NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3952

EFFECTS OF HORIZONTAL-TAIL POSITION AND A WING LEADING-EDGE MODIFICATION CONSISTING OF A FULL-SPAN FLAP AND A PARTIAL-SPAN CHORD-EXTENSION ON THE AERODYNAMIC CHARACTERISTICS IN PITCH AT HIGH SUBSONIC SPEEDS OF A MODEL WITH A 45° SWEPTBACK WING

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Langley Aeronautical Laboratory
Langley Field, Va.

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EFFECTS OF HORIZONTAL-TAIL POSITION AND A WING LEADING-EDGE MODIFICATION CONSISTING OF A FULL-SPAN FLAP AND A PARTIAL-SPAN CHORD-EXTENSION ON THE AERODYNAMIC CHARACTERISTICS IN PITCH AT HIGH SUBSONIC SPEEDS OF A MODEL WITH A 45° SWEPTBACK WING[1]

By William D. Morrison, Jr., and William J. Alford, Jr.

SUMMARY

An investigation was conducted in the Langley high-speed 7- by 10-foot tunnel to determine the effects of varying the horizontal-tail position relative to the wing chord plane on the aerodynamic characteristics in pitch of a general research model having a 45° sweptback wing of aspect ratio 4, taper ratio 0.30, and NACA 65A006 airfoil sections. The investigation also included the effects of a wing modification consisting of a full-span leading-edge flap deflected 6° and an outboard partial-span chord-extension. The test Mach numbers ranged from 0.40 to 0.93 and the corresponding Reynolds numbers ranged from about 2,000,000 to 3,000,000.

In the range of horizontal-tail positions investigated, the most desirable pitching-moment characteristics obtained, either with or without the wing modification, were with the lowest tail position (0.139 semispan below wing chord plane extended). The wing modification provided considerable improvement in pitching-moment characteristics for tail positions above the chord plane extended. The improvements obtained at Mach numbers near 0.90 were much smaller, however, than those obtained at lower Mach numbers.

INTRODUCTION

Very comprehensive studies of the effects of horizontal-tail position on the overall longitudinal stability characteristics of complete airplane configurations have been conducted at low speeds (refs. 1 and 2),

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[1]Supersedes declassified NACA Research Memorandum L53E06 by William D. Morrison, Jr., and William J. Alford, Jr., 1953.

but at the present time knowledge of tail-position effects at high subsonic speeds is quite limited.

This investigation was performed to determine the effects of horizontal-tail position relative to the wing chord plane on the longitudinal stability characteristics of a general research model at Mach numbers from 0.40 to 0.93. The wing used in this investigation had 45° of sweep, an aspect ratio of 4, a taper ratio of 0.3, and an NACA 65A006 airfoil section. At each tail position, tests were made of the model with the basic wing and of the model with a wing modification consisting of a full-span leading-edge flap deflected 6° and an outboard partial-span chord-extension. This particular wing modification was developed during a previous investigation (ref. 3) of the same model without tail surfaces and is not necessarily the optimum wing modification with tail surfaces added.

COEFFICIENTS AND SYMBOLS

All data are presented about the wind axes. Unless otherwise specified, all pitching-moment data are referred to the quarter chord of the mean aerodynamic chord. Coefficients are based on the original wing area of 2.25 square feet.

C_L lift coefficient, Lift/qS

C_D drag coefficient, Drag/qS

C_m pitching-moment coefficient, Pitching moment/$qS\bar{c}$

q dynamic pressure, $\frac{\rho V^2}{2}$, lb/sq ft

ρ mass density of air, slugs/cu ft

V free-stream velocity, fps

M Mach number

α angle of attack, deg

S wing area, 2.25 sq ft

c local wing chord, ft

$\bar{c}$ wing mean aerodynamic chord, $\frac{2}{S}\int_0^{b/2} c^2\,dy$, ft

$\bar{c}_t$	horizontal-tail mean aerodynamic chord, ft
b	span of wing, ft
l	tail length (measured from 0.25 wing mean aerodynamic chord to 0.25 mean aerodynamic chord of horizontal tail), ft
R	Reynolds number
y	spanwise distance from plane of symmetry, ft
Z_H	horizontal-tail position (positive tail position above chord plane extended), percent wing semispan
i_t	angle of horizontal-tail setting (measured with respect to fuselage center line), deg

MODELS AND APPARATUS

The complete research model of this investigation is shown mounted on the sting support in the Langley high-speed 7- by 10-foot tunnel in figure 1. Except for the addition of the tail assembly, the model is the same as that used for the tests reported in reference 3. The fuselage was a body of revolution - the center line being the reference for all flap and tail angles. Ordinates of the fuselage are given in table I. A drawing of the model with horizontal tail located at $Z_H = 25.6$ percent wing semispan is shown as figure 2. The vertical tail shown in figure 2 was used only in conjunction with the horizontal-tail position shown therein. For the lower horizontal-tail positions, the vertical tail was replaced by a small tail-support fitting. (See fig. 3.) In figure 3 configurations A, B, and C refer to tail positions Z_H of -13.9, 13.9, and 25.6 percent semispan, respectively. A tail position of 13.9 percent wing semispan above the chord plane extended was obtained with the tail-support fitting attached at the top of the fuselage. By rotating the tail cone through 180°, the tail could be located 13.9 percent wing semispan below the chord plane extended. Provision was made to test the model with horizontal-tail angle settings of -3°, 0°, and 3° at each tail position. (Zero tail incidence was not used for the tail located at 25.6 percent wing semispan above the chord plane extended.) The tail length remained constant for all tail positions.

The basic wing of this investigation had 45° of sweepback referred to the quarter-chord line, an aspect ratio of 4, a taper ratio of 0.3, and an NACA 65A006 airfoil section measured parallel to the free stream. The wing was of a solid aluminum construction. The model was fitted with a deflectable full-span leading-edge flap with hinge line at 0.20c of the basic wing. The portion of the leading-edge flap extending from 0.65b/2 to the wing tip could be removed and reattached through an insert to provide an outboard leading-edge chord-extension of $0.10\bar{c}$. One series of tests of the model was made with the basic wing, and a second series of tests was made with the model having a wing modification consisting of 6° deflection of the leading-edge flap in combination with the outboard chord-extension.

The model was tested on the sting-support system shown in figure 1. With this sting support, the model can be remotely pitched through an angle-of-attack range of 28°.

Forces and moments were measured by means of an electrical strain-gage balance system located within the model fuselage.

The variation of the mean Reynolds number (based on $\bar{c}$) with Mach number is presented as figure 4.

CORRECTIONS

Tunnel blockage corrections were determined by the method of reference 4 and were applied to the Mach numbers and dynamic pressures. Jet-boundary corrections, applied to both the angle of attack and drag, were determined by the method of reference 5. Jet-boundary corrections to pitching moment were found to be negligible and hence were not applied.

The drag data have been corrected to correspond to a pressure at the base of the model equal to free-stream static pressure. For this correction, the base pressure was determined by measuring the pressure inside the fuselage at a point about 9 inches forward of the base. For a more detailed explanation of this correction, see reference 3.

The angle of attack has been corrected for deflection of the sting-support system under load. Possible aeroelastic effects of the wing and tail combinations have not been evaluated; however, wing-alone effects have been evaluated and may be found in reference 3.

No tare corrections were applied to these data. Previous investigations have shown that the tare corrections to lift and pitching moment are negligible for the wing-fuselage combination, but the effects of adding the horizontal tail as yet have not been thoroughly investigated. Limited tare tests, with a yoke sting setup, have indicated that the major effect would be a small trim change with little effect on the stability.

RESULTS AND DISCUSSION

The basic data of this investigation obtained for three horizontal-tail positions and horizontal-tail settings, with and without the wing leading-edge modification, are presented as figures 5 to 12. (Data were not obtained at zero incidence for the tail located at 25.6 percent semi-span above the wing chord plane extended.) In order to expedite the publication of these data, only a very brief analysis of the pitch characteristics is included. No attempt has been made to evaluate downwash characteristics, although the data obtained with the different horizontal-tail settings, along with the tail-off data of reference 3, will permit such evaluations. An analysis of the lift, drag, and lift-drag ratios for the wing-fuselage combination, with and without the leading-edge modifications considered herein, may be found in reference 3.

In using the data presented in the present paper, consideration should be given to the fact that the vertical tail was used only in conjunction with the horizontal-tail position $Z_H = 25.6$ percent semi-span. Because of the absence of the vertical tail for the test involving the two lower positions of the horizontal tail, the drag data are not considered to be directly comparable for all tail positions. It is believed, however, that any possible influence of the vertical tail on lift and pitching-moment characteristics is of secondary importance.

The pitching-moment characteristics obtained with a horizontal-tail setting of -3° and with each of the tail positions are summarized and compared with the tail-off results from reference 3 in figure 13. The results are presented with reference to an assumed center-of-gravity location of $0.25\bar{c}$ (as was used in presenting the basic data) and with reference to an assumed center-of-gravity location at $0.35\bar{c}$. Mach numbers of 0.80 and 0.90 are considered.

For the range of tail positions investigated, lowering the horizontal tail resulted in a reduction in the severity of the pitch-up tendency at the high lift coefficients. Addition of the wing leading-edge modification, for any of the tail positions investigated, was very effective in reducing the high-lift pitch-up and in increasing the lift coefficient at which the pitch-up occurs; however, the effectiveness of the leading-edge modification became smaller as the tail was lowered. Neither the variation of tail position nor the addition of the wing leading-edge modification affected the low-lift stability to any appreciable degree.

The data presented at a Mach number of 0.80 are, in general, representative of the lower Mach number results for which the effectiveness of the wing leading-edge modification in improving high-lift stability characteristics is relatively high. The effectiveness of the wing modification was considerably smaller at a Mach number of 0.90, although some advantage - particularly, with regard to the lift coefficient at which pitch-up occurs - still is indicated.

The basic data (figs. 5 to 12) show that improvements in lift and drag characteristics result from use of the wing leading-edge modification and are of about the same magnitude as those indicated for the wing-fuselage combination in reference 3.

CONCLUSIONS

An investigation of the effects of horizontal-tail position relative to wing chord plane and a wing leading-edge modification, consisting of a full-span flap and an outboard partial-span chord-extension, on the aerodynamic characteristics in pitch at high subsonic speeds of a model with a 45° sweptback wing indicate the following:

1. For the range of horizontal-tail position investigated, the lowest tail position (13.9 percent wing semispan below the chord plane extended) provided the most desirable static pitching-moment characteristics for either the basic or modified wing.

2. The wing modification provided considerable improvement in pitching-moment characteristics for the tail positions 13.9 and 25.6 percent wing semispan above the chord plane extended. These improvements were much smaller at Mach numbers near 0.90, however, than at lower Mach numbers.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 30, 1953.

REFERENCES

1. Queijo, M. J., Jaquet, Byron M., and Wolhart, Walter D.: Wind-Tunnel Investigation at Low Speed of the Effects of Chordwise Wing Fences and Horizontal-Tail Position on the Static Longitudinal Stability Characteristics of an Airplane Model With a 35° Sweptback Wing. NACA Rep. 1203, 1954. (Supersedes NACA RM L50K07 by Queijo and Jaquet and RM L51H17 by Queijo and Wolhart.)

2. Furlong, G. Chester, and McHugh, James G.: A Summary and Analysis of the Low-Speed Longitudinal Characteristics of Swept Wings at High Reynolds Numbers. NACA RM L52D16, 1952.

3. Spreemann, Kenneth P., and Alford, William J., Jr.: Investigation of the Effects of Leading-Edge Chord-Extensions and Fences in Combination With Leading-Edge Flaps on the Aerodynamic Characteristics at Mach Numbers From 0.40 to 0.93 of a 45° Sweptback Wing of Aspect Ratio 4. NACA TN 3845, 1957. (Supersedes NACA RM L53A09a.)

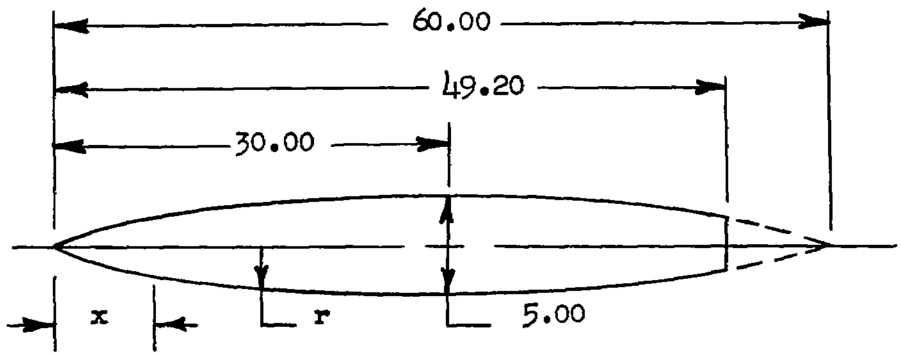
4. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, With Consideration of the Effect of Compressibility. NACA Rep. 995, 1950. (Supersedes NACA RM A7B28.)

5. Gillis, Clarence L., Polhamus, Edward C., and Gray, Joseph L., Jr.: Charts for Determining Jet-Boundary Corrections for Complete Models in 7- by 10-Foot Closed Rectangular Wind Tunnels. NACA WR L-123, 1945. (Formerly NACA ARR L5G31.)

TABLE I.

FUSELAGE ORDINATES

[Basic fineness ratio 12; actual fineness ratio 9.8 achieved by cutting off rear portion of body]



Ordinates, in.	
x	r
0	0
.30	.139
.45	.179
.75	.257
1.50	.433
3.00	.723
4.50	.968
6.00	1.183
9.00	1.556
12.00	1.854
15.00	2.079
18.00	2.245
21.00	2.360
24.00	2.438
27.00	2.486
30.00	2.500
33.00	2.478
36.00	2.414
39.00	2.305
42.00	2.137
49.20	1.650
L.E. radius = 0.030 in.	

Figure 1.- Photograph of a general transonic research model in the test section of the Langley high-speed 7- by 10-foot tunnel. High horizontal-tail position (Z_H = 25.6 percent wing semispan).

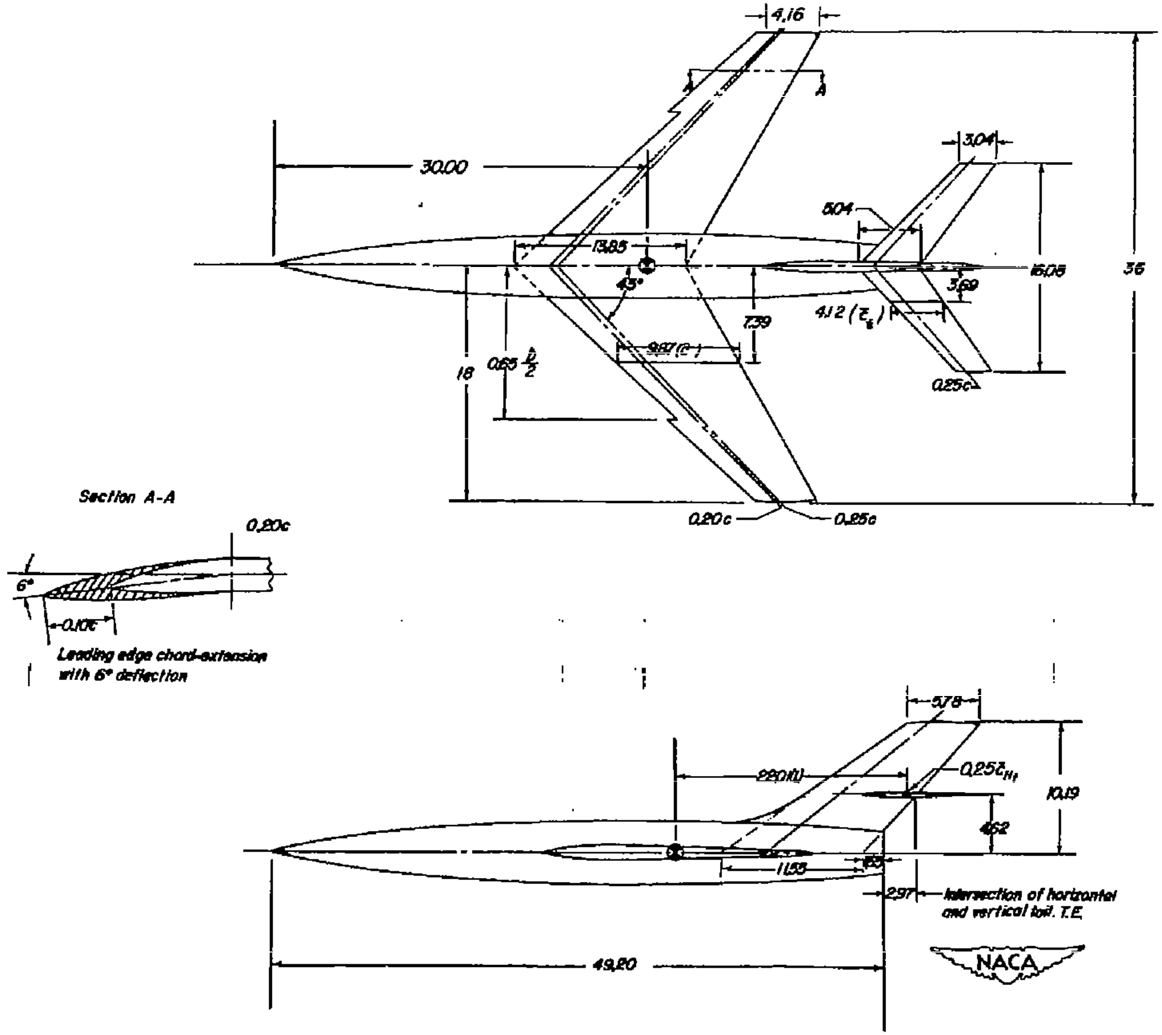


Figure 2.- Drawing of a general research model showing full-span leading-edge deflection and partial-span chord-extensions. All dimensions are in inches.

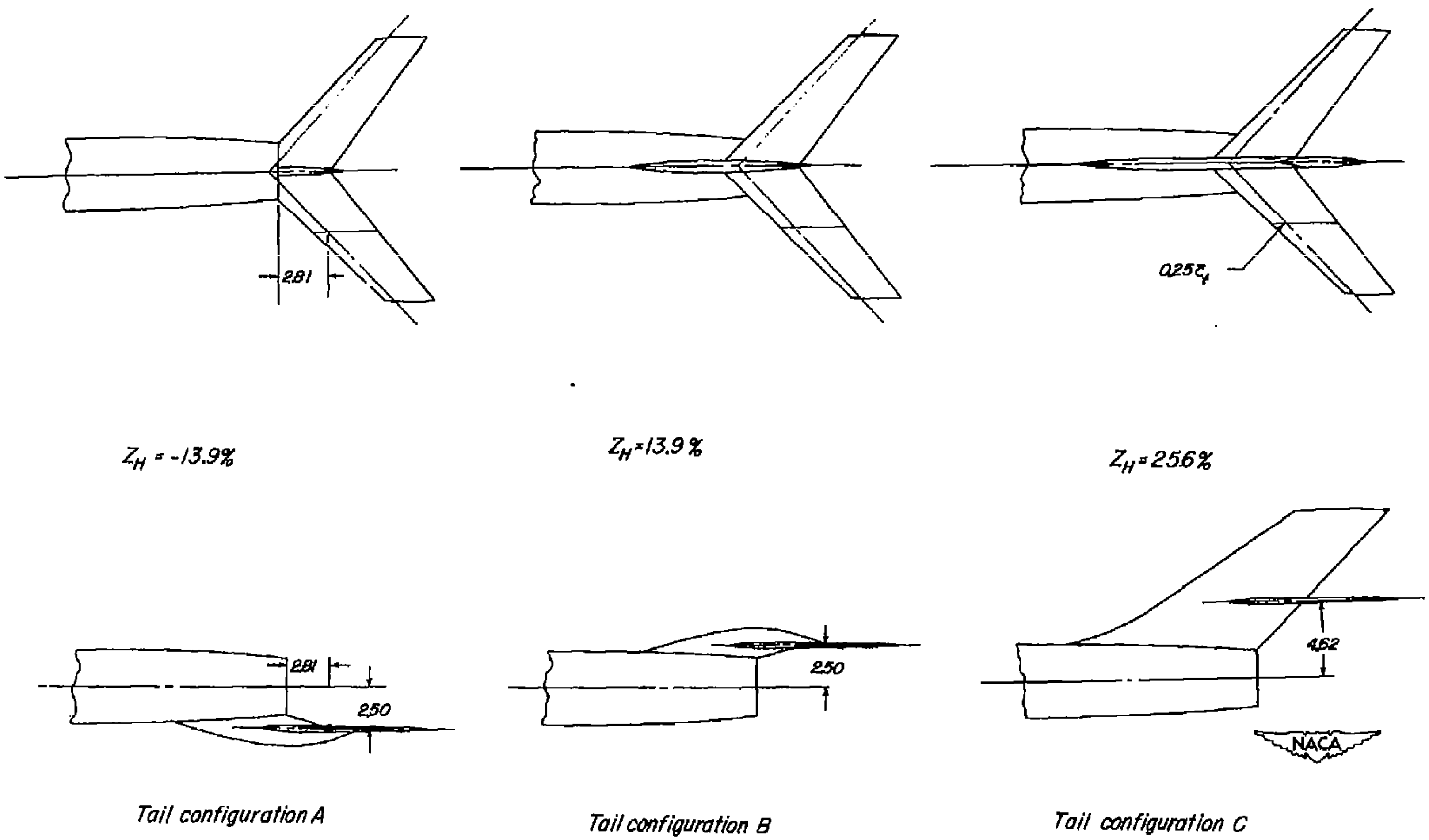


Figure 3.- Drawing of the tail assembly of a general research model showing three positions of the horizontal tail. All dimensions are in inches. Tail length l of 22.01 inches common to all tail positions; same horizontal tail used for all tail positions.

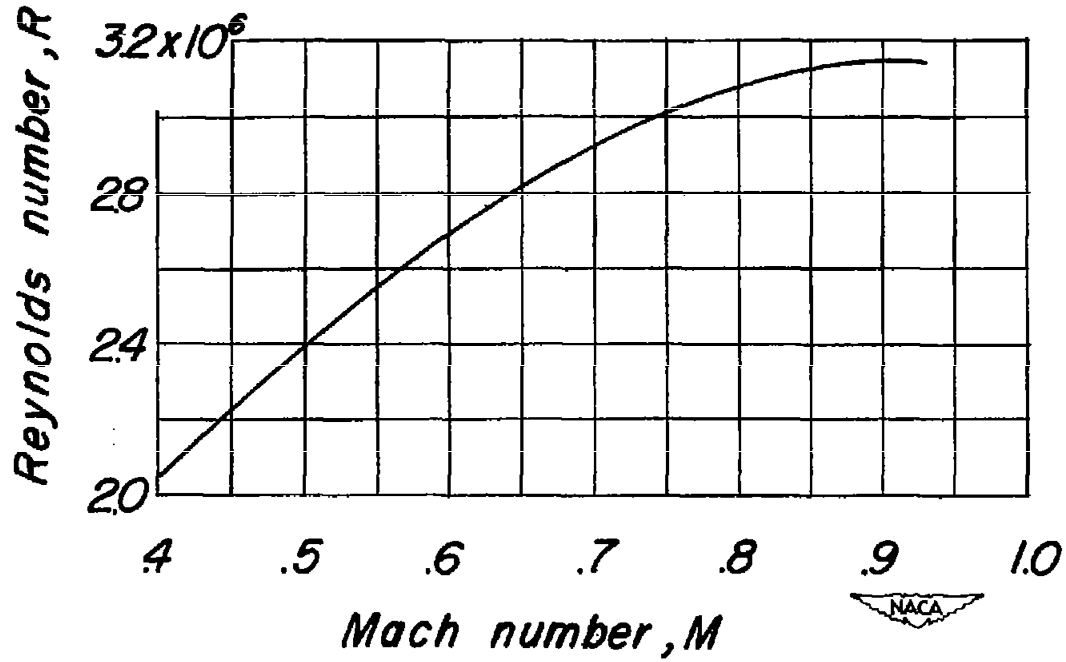
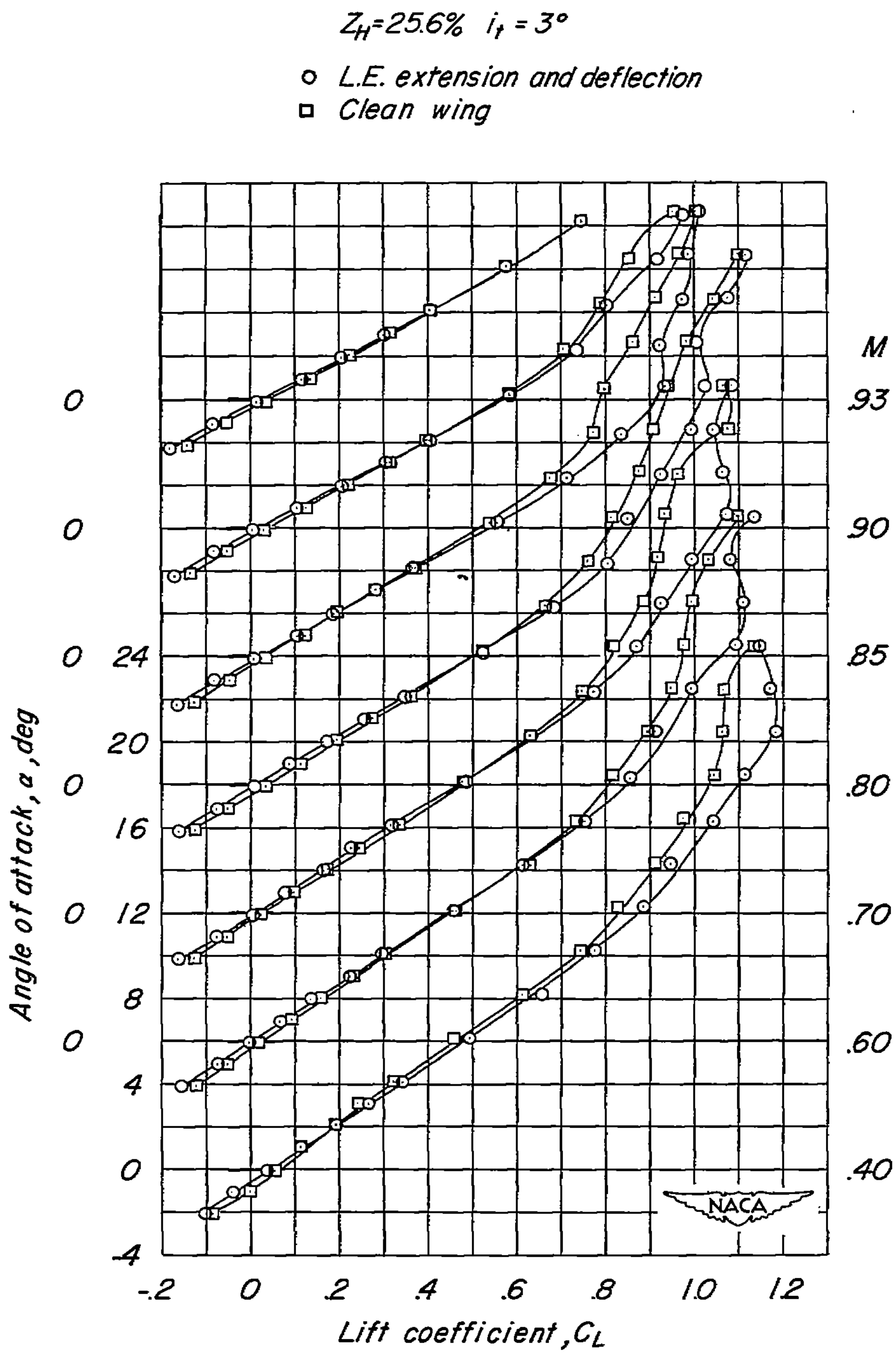
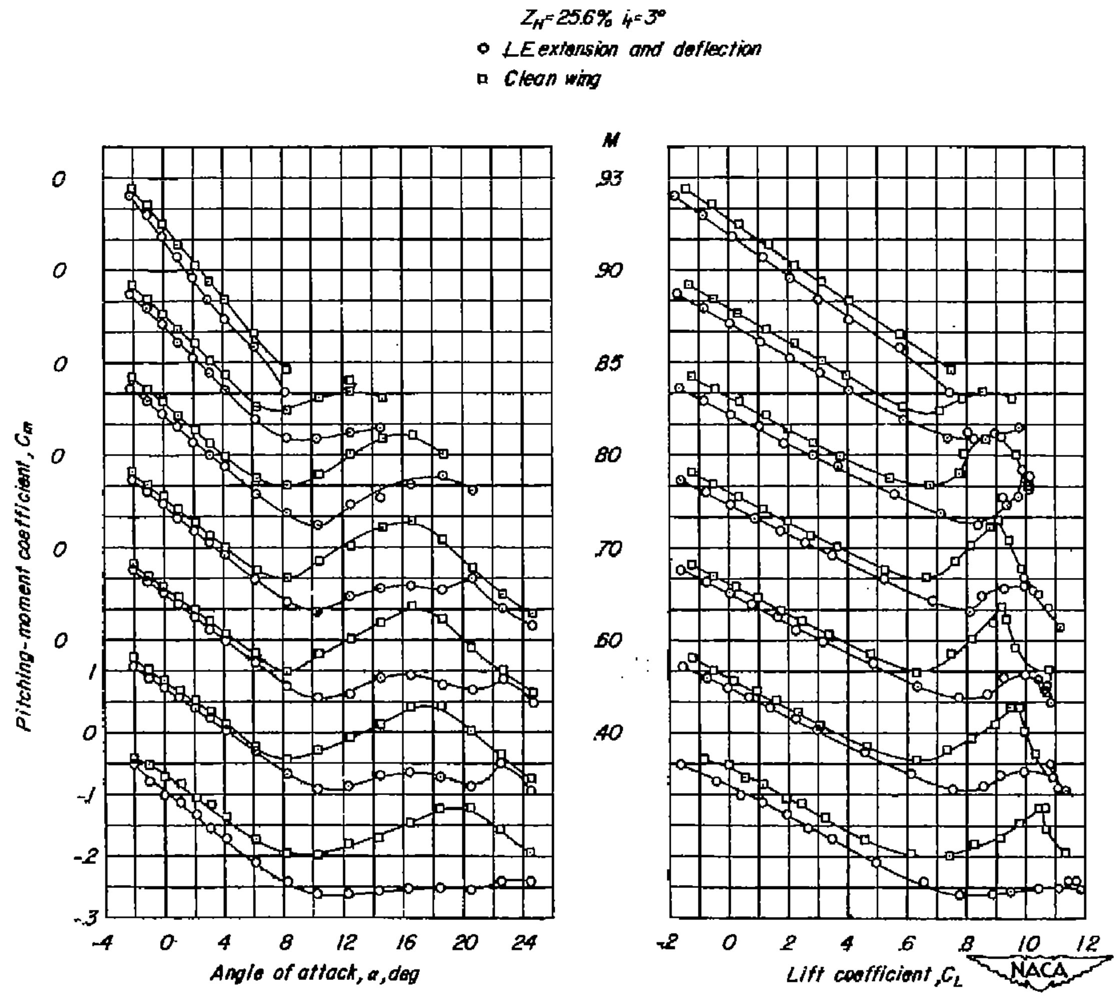


Figure 4.- Variation of mean test Reynolds number with Mach number.



(a) α against C_L.

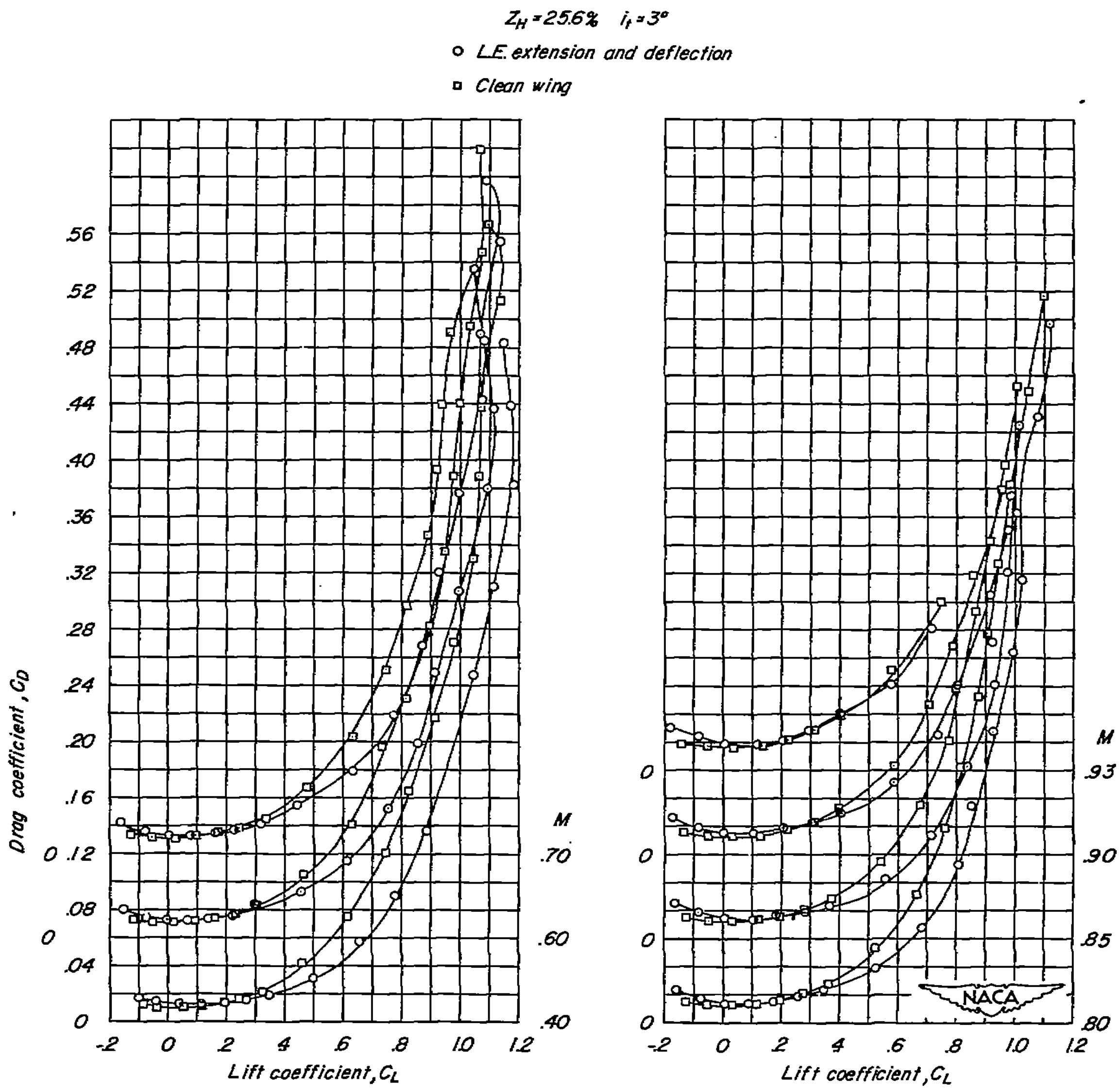
Figure 5.- Effects of a 6° full-span leading-edge-flap deflection and partial-span chord-extension on the aerodynamic characteristics in pitch of a general research model with tail configuration C. Z_H = 25.6 percent semispan; i_t = 3°.



(b) C_m against α.

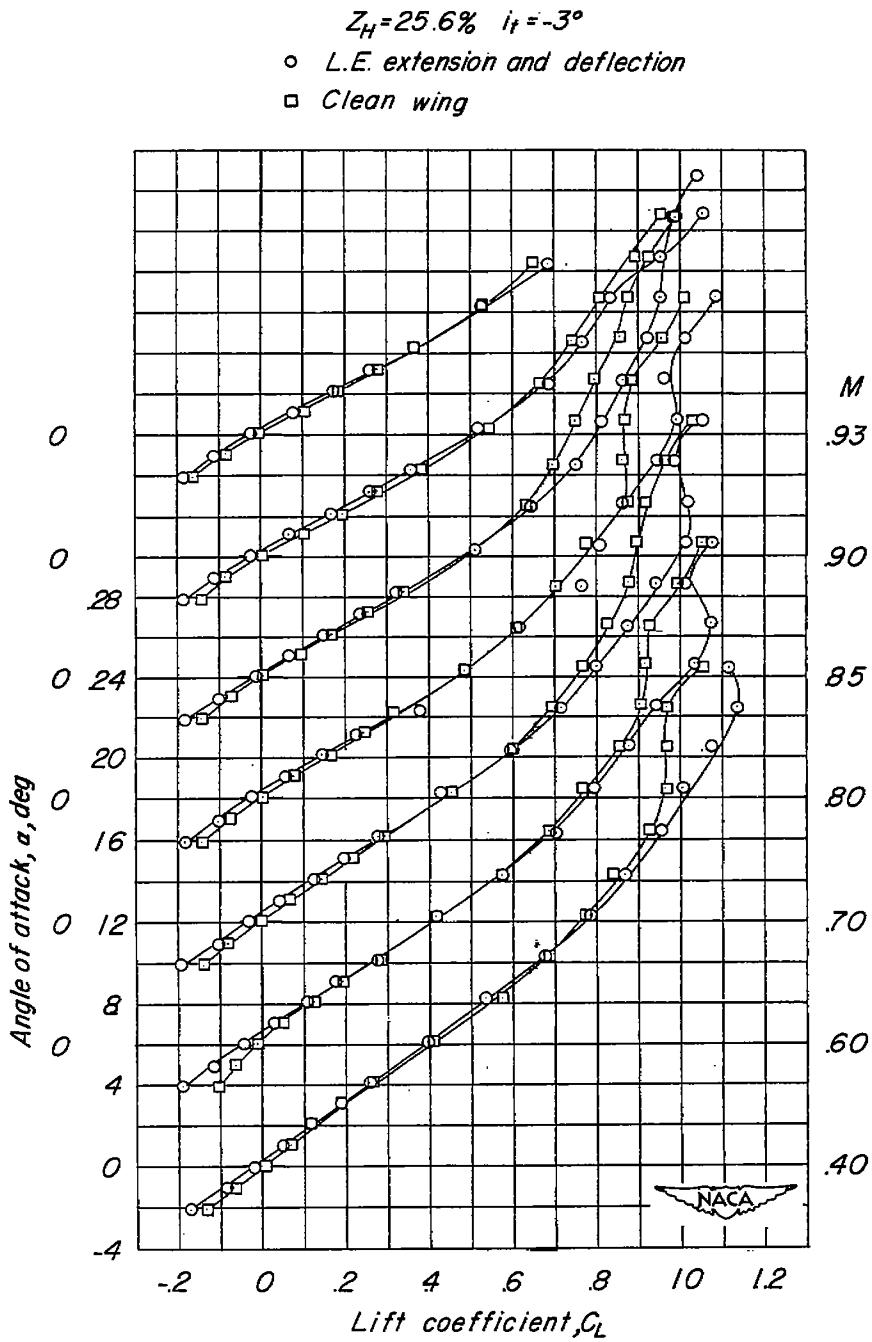
(c) C_m against C_L.

Figure 5.- Continued.



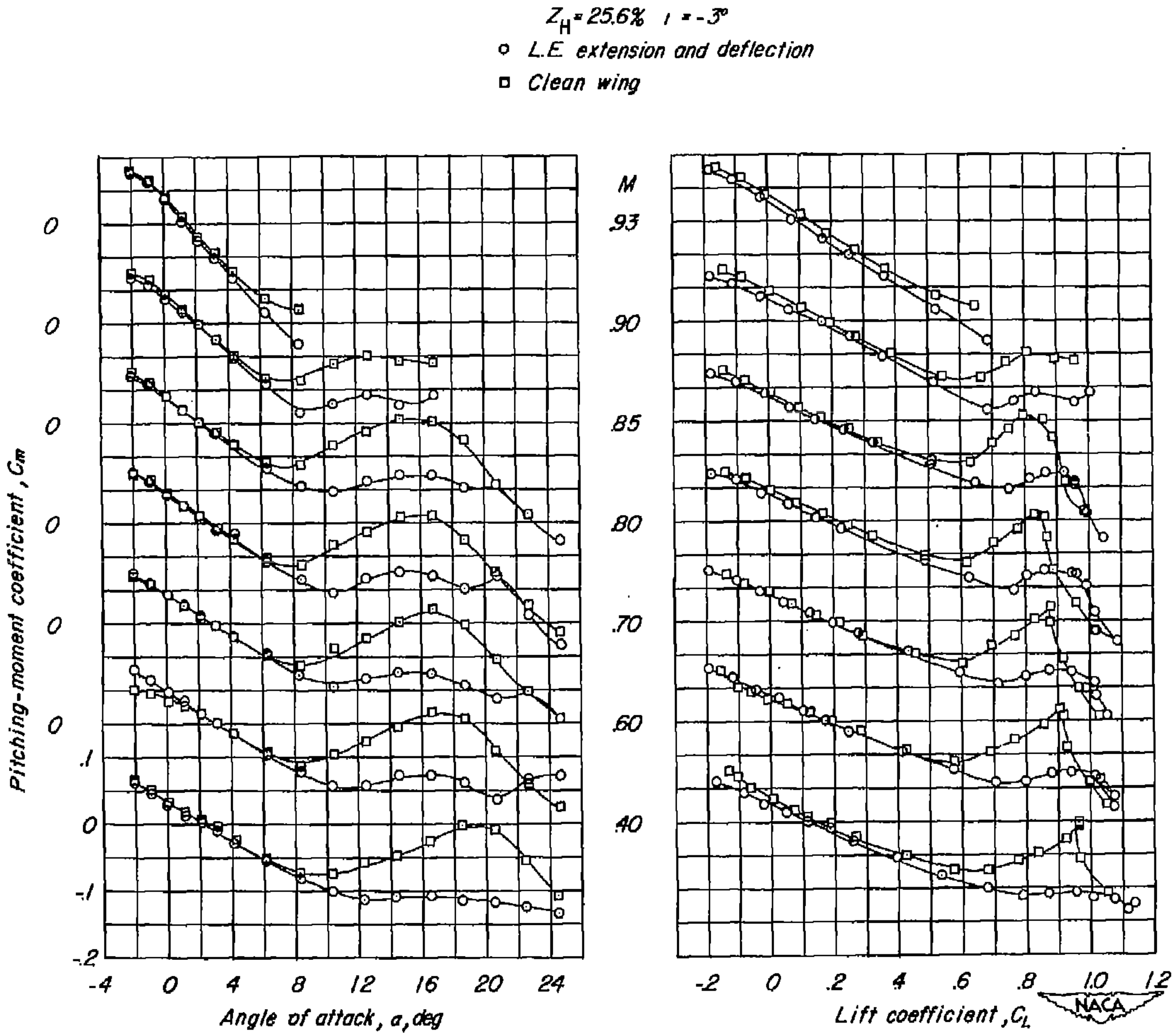
(d) C_D against C_L.

Figure 5.- Concluded.



(a) α against C_L.

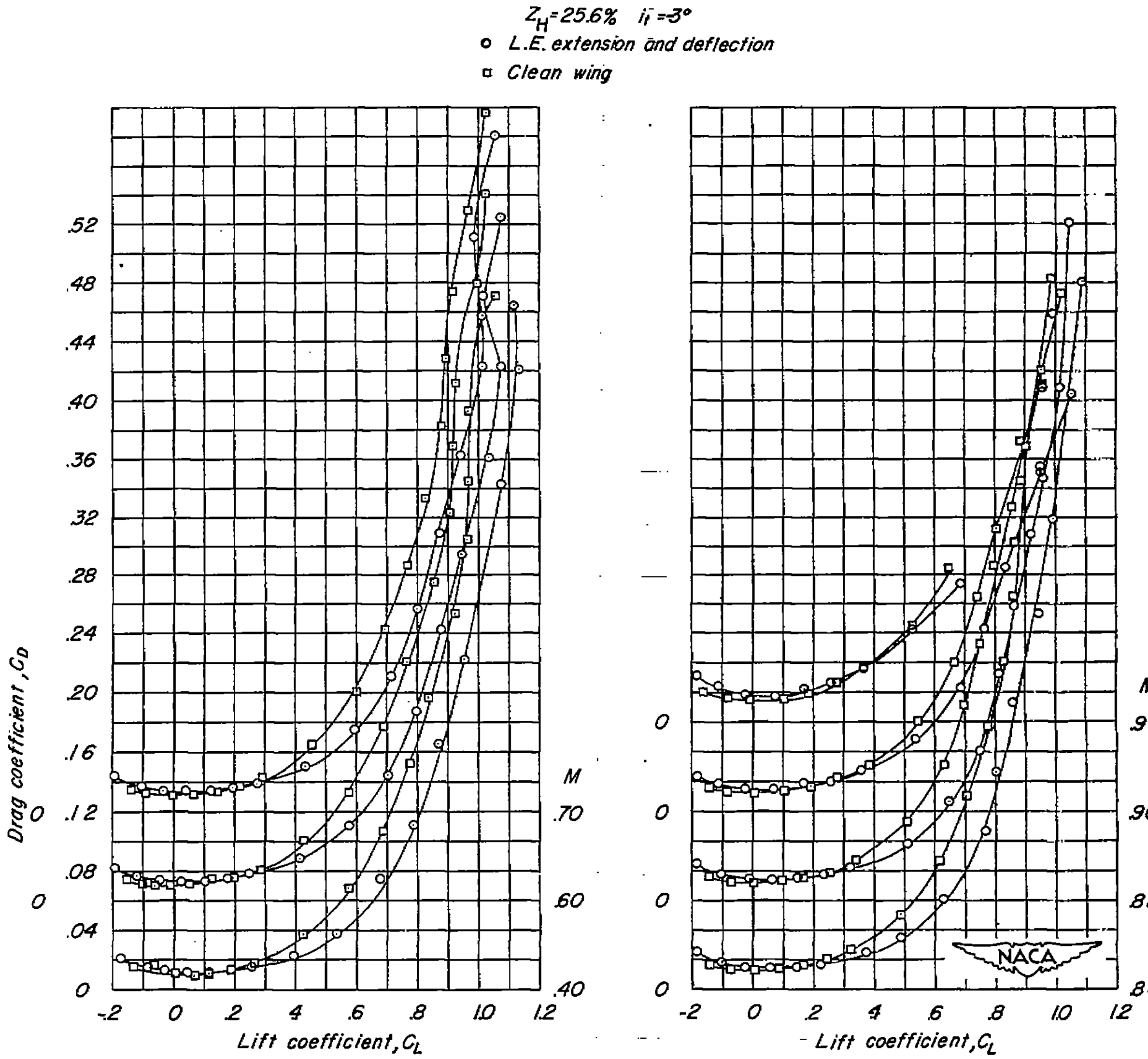
Figure 6.- Effects of a 6° full-span leading-edge-flap deflection and partial-span chord-extension on the aerodynamic characteristics in pitch of a general research model with tail configuration C. Z_H = 25.6 percent semispan; $i_t = -3^{\circ}$.



(b) C_m against α.

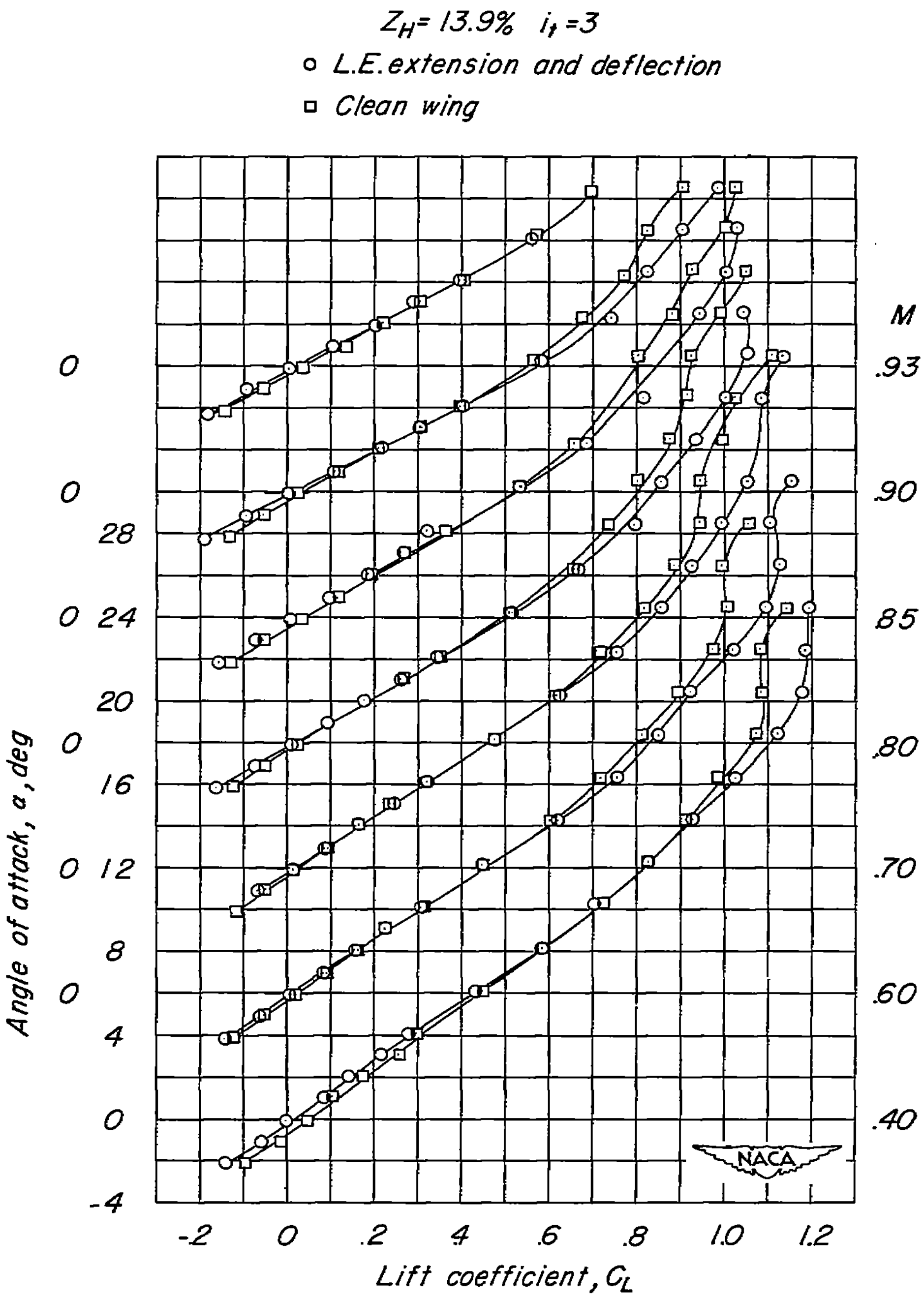
(c) C_m against C_L.

Figure 6.- Continued.



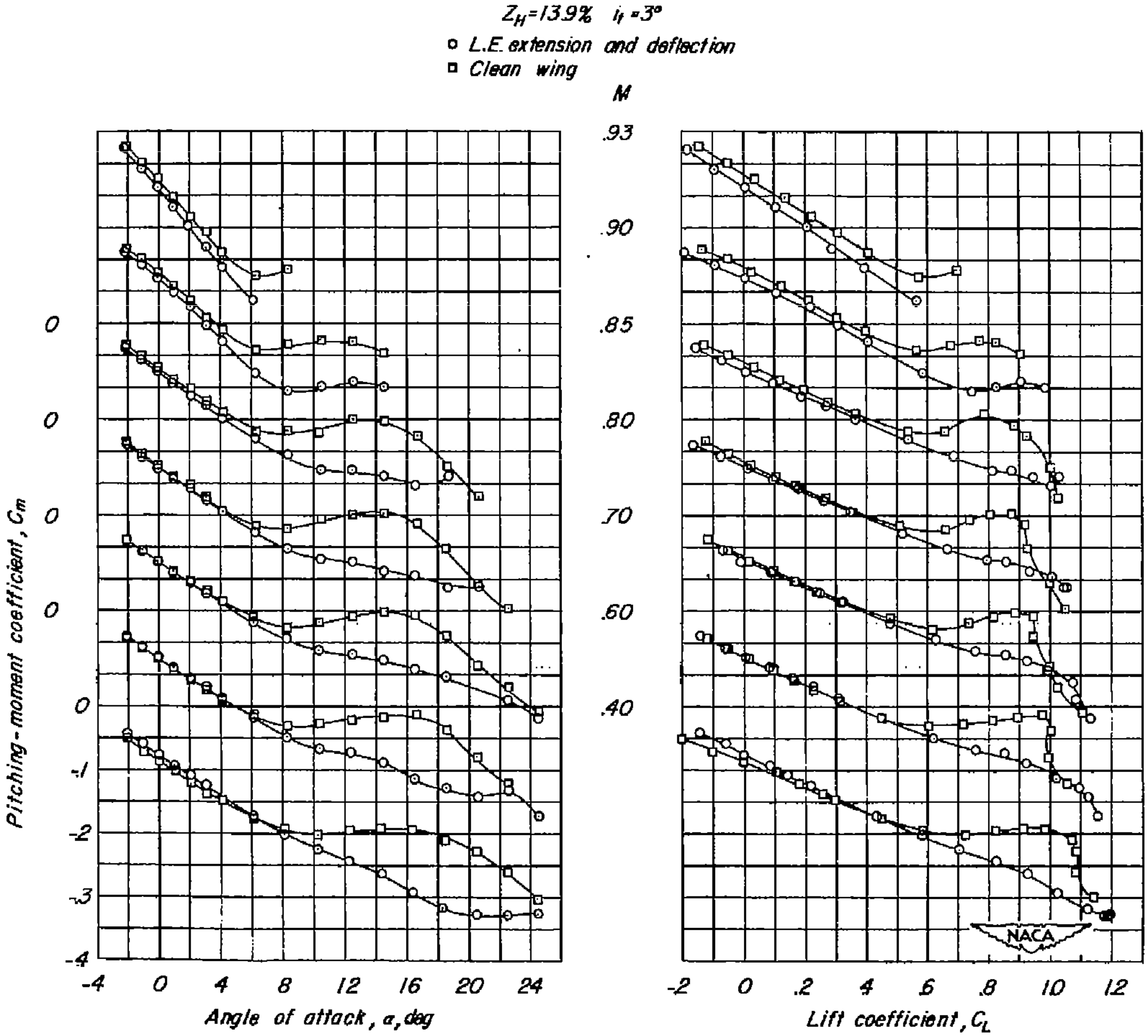
(d) C_D against C_L.

Figure 6.- Concluded.



(a) α against C_L.

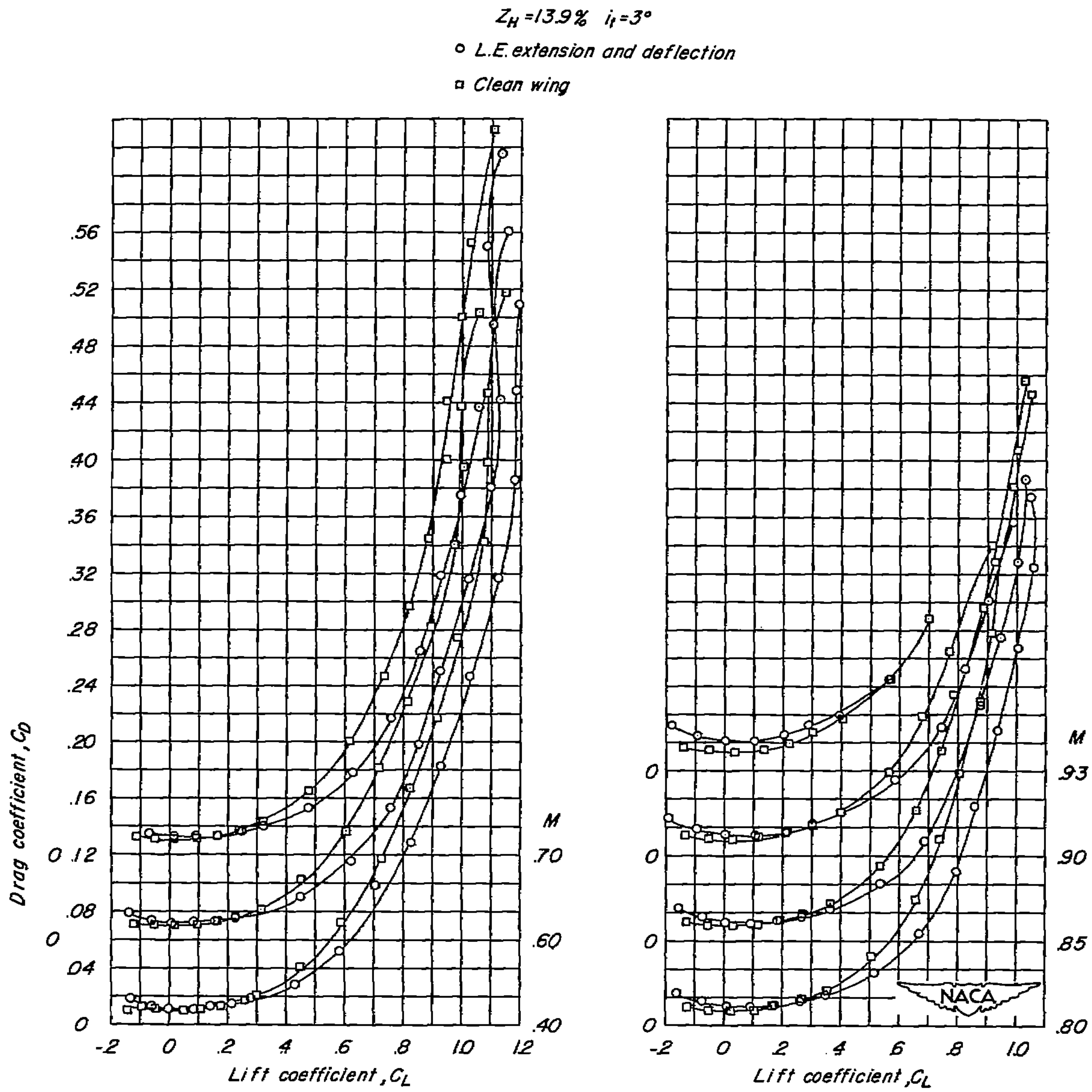
Figure 7.- Effects of a 6° full-span leading-edge-flap deflection and partial-span chord-extension on the aerodynamic characteristics in pitch of a general research model with tail configuration B. Z_H = 13.9 percent semispan; $i_t = 3^{\circ}$.



(b) C_m against α.

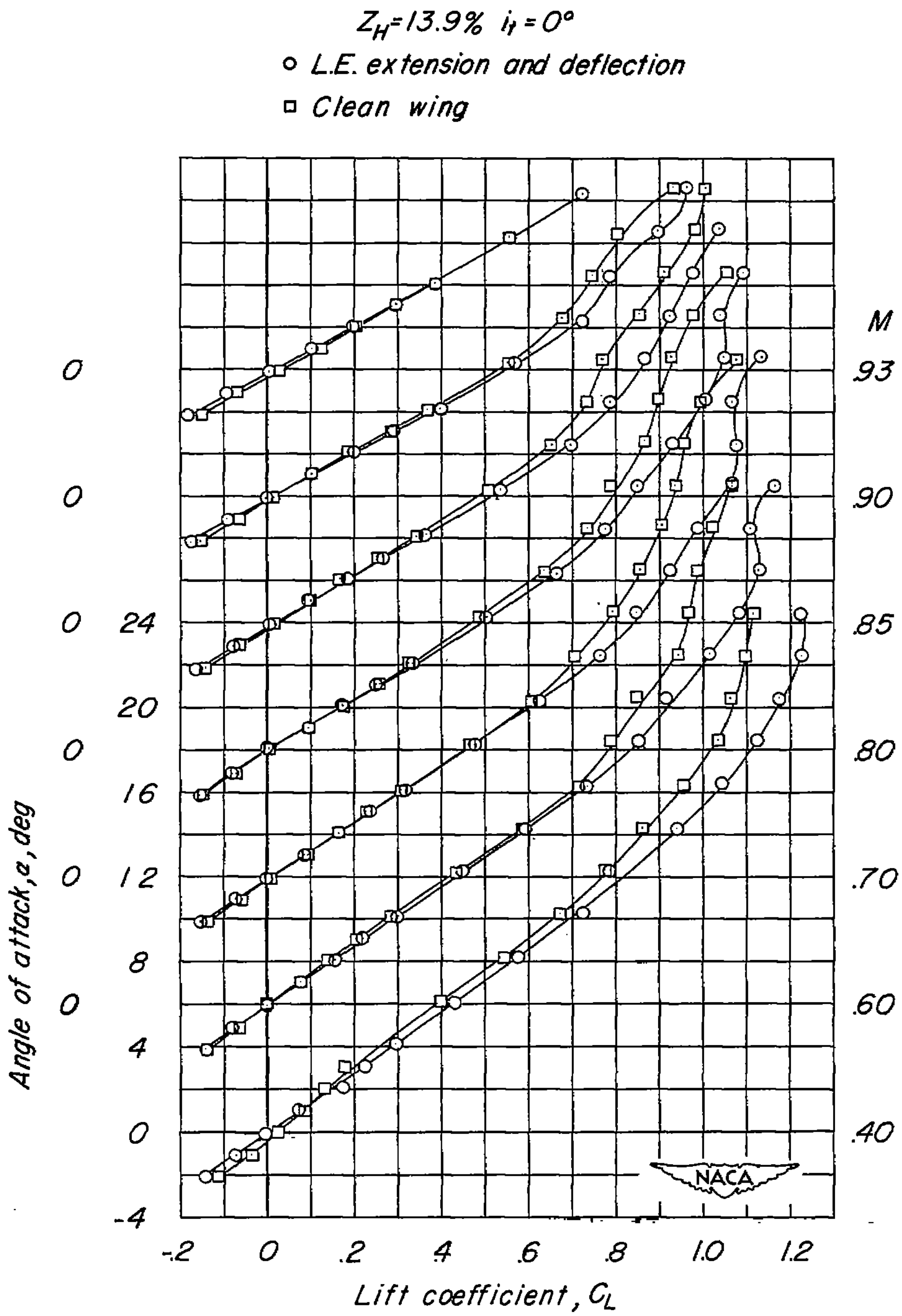
(c) C_m against C_L.

Figure 7.- Continued.



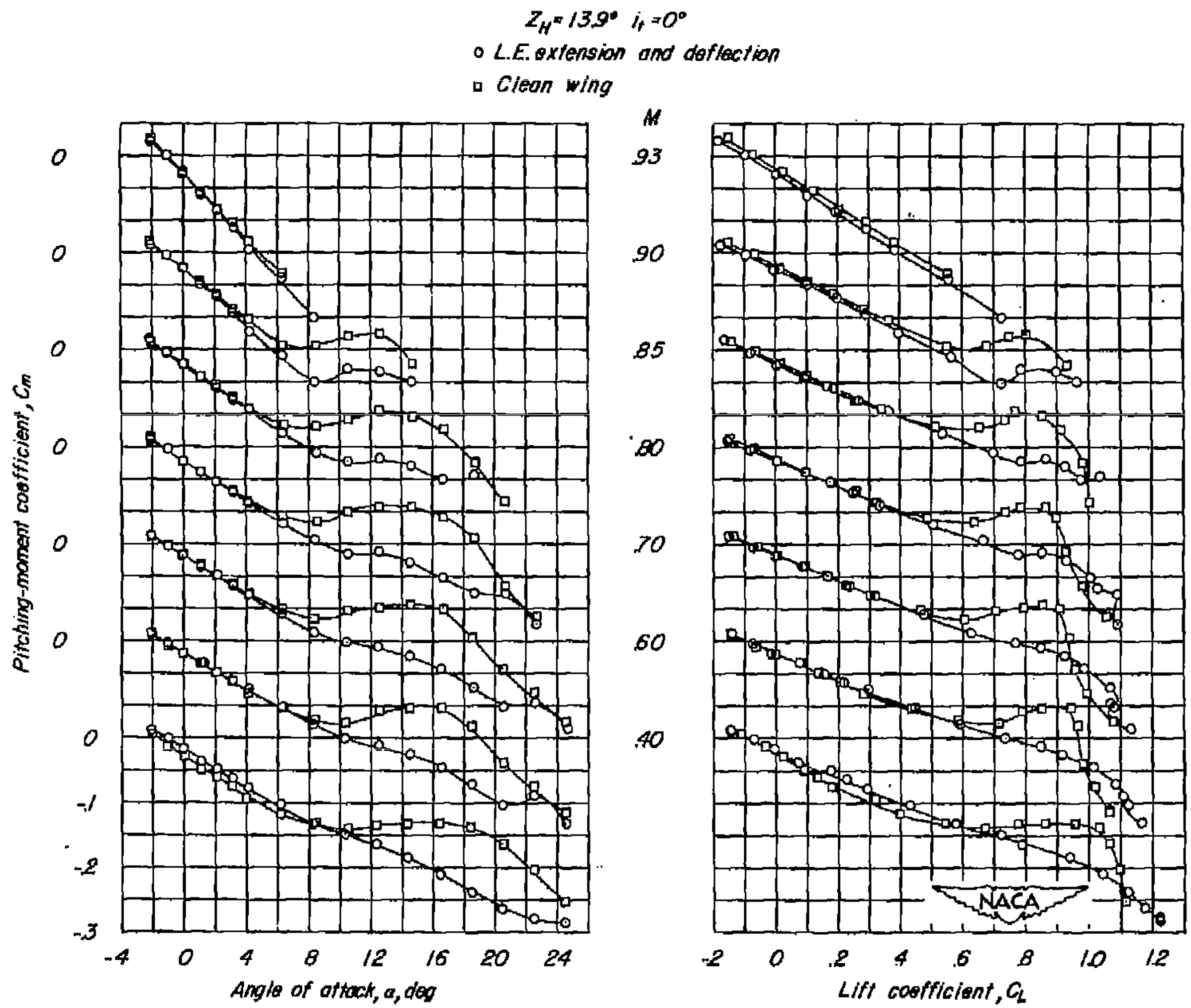
(d) C_D against C_L.

Figure 7.- Concluded.



(a) α against C_L.

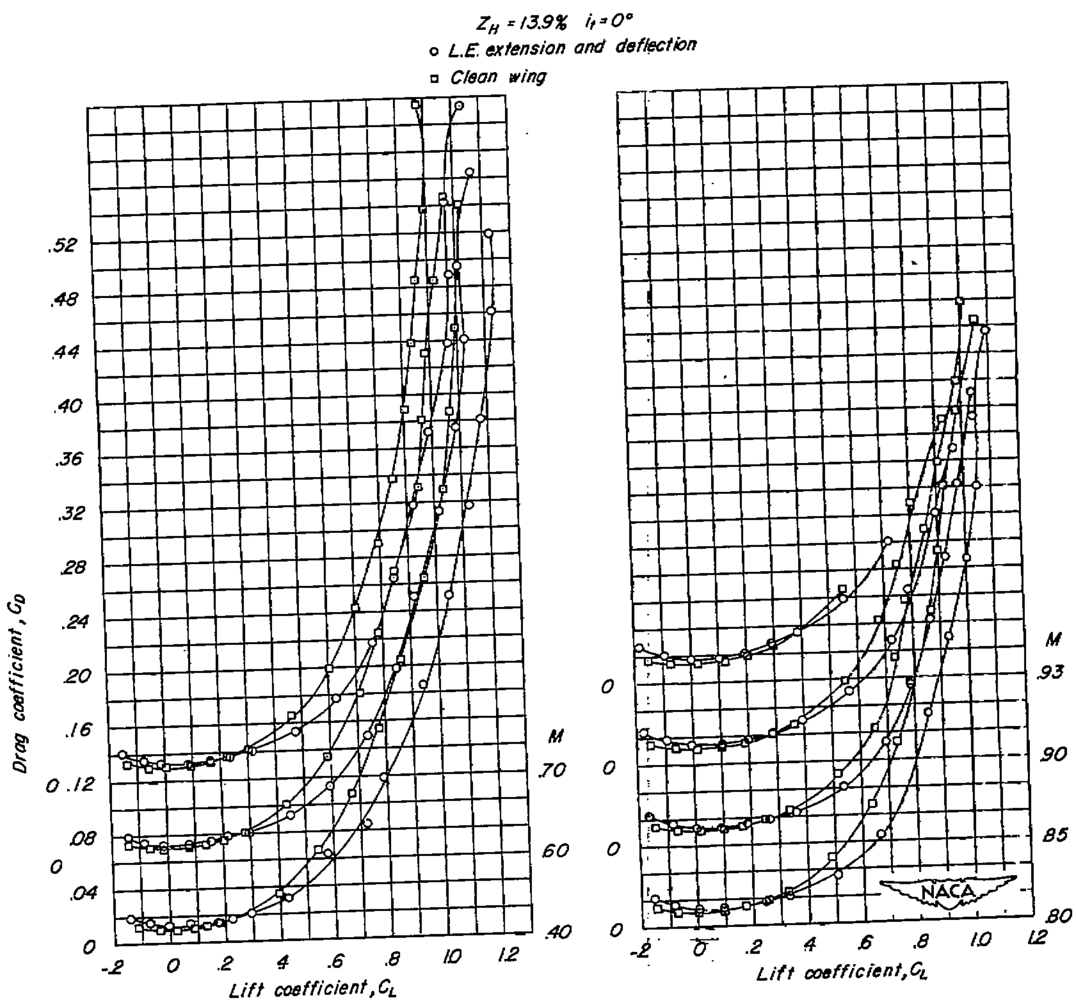
Figure 8.- Effects of a 6° full-span leading-edge-flap deflection and partial-span chord-extension on the aerodynamic characteristics in pitch of a general research model with tail configuration B. Z_H = 13.9 percent semispan; i_t = 0°.



(b) C_m against α.

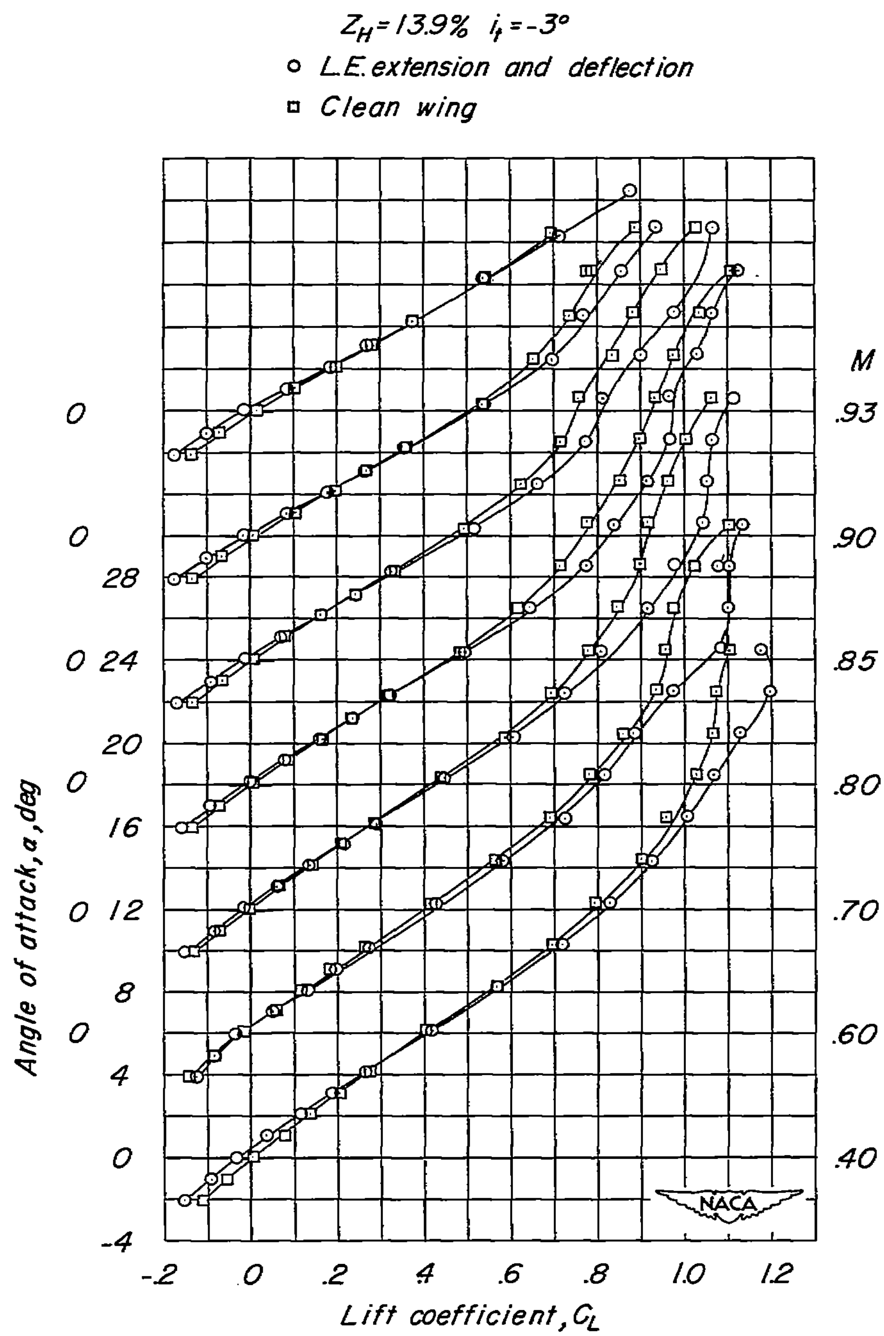
(c) C_m against C_L.

Figure 8.- Continued.



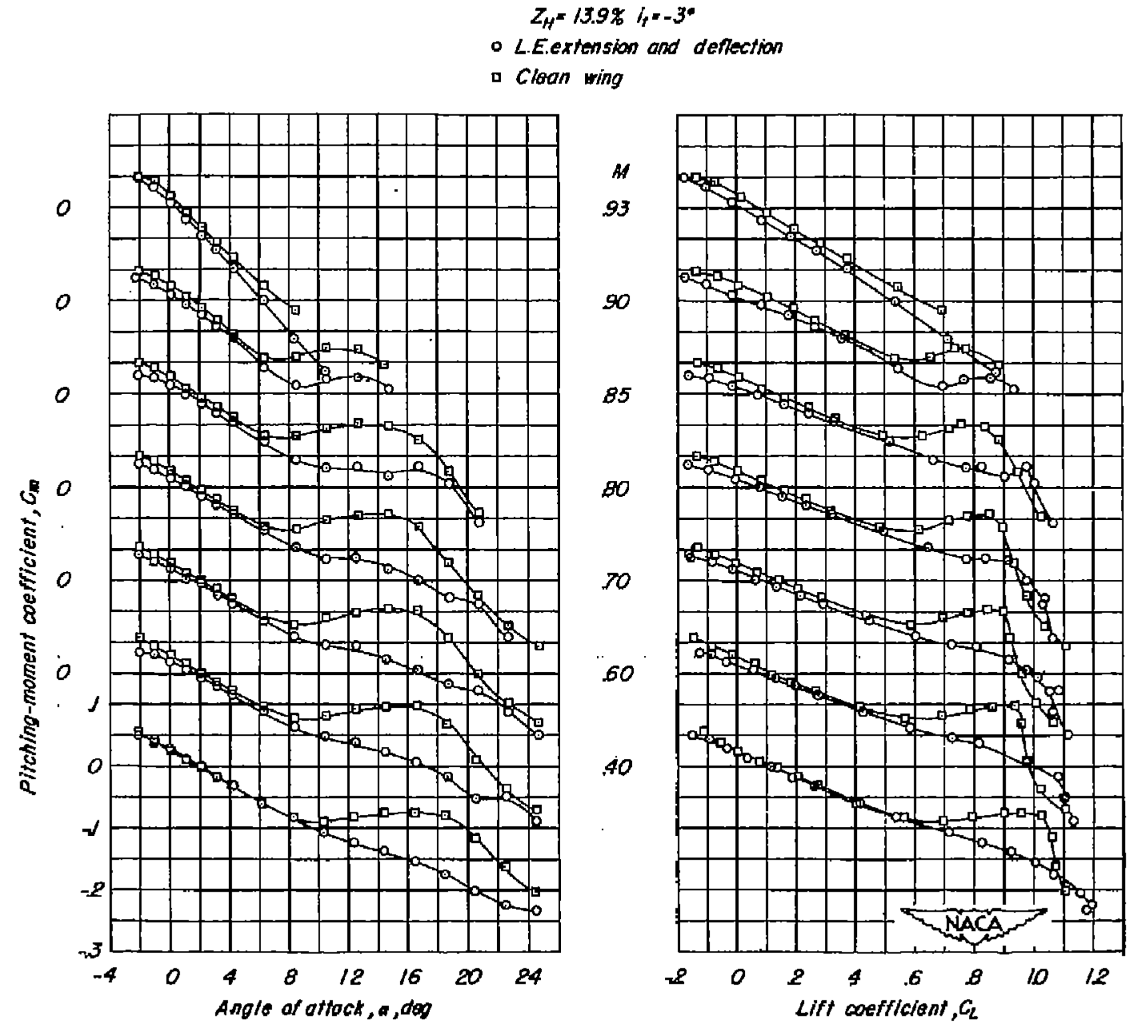
(d) C_D against C_L.

Figure 8.- Concluded.



(a) α against C_L.

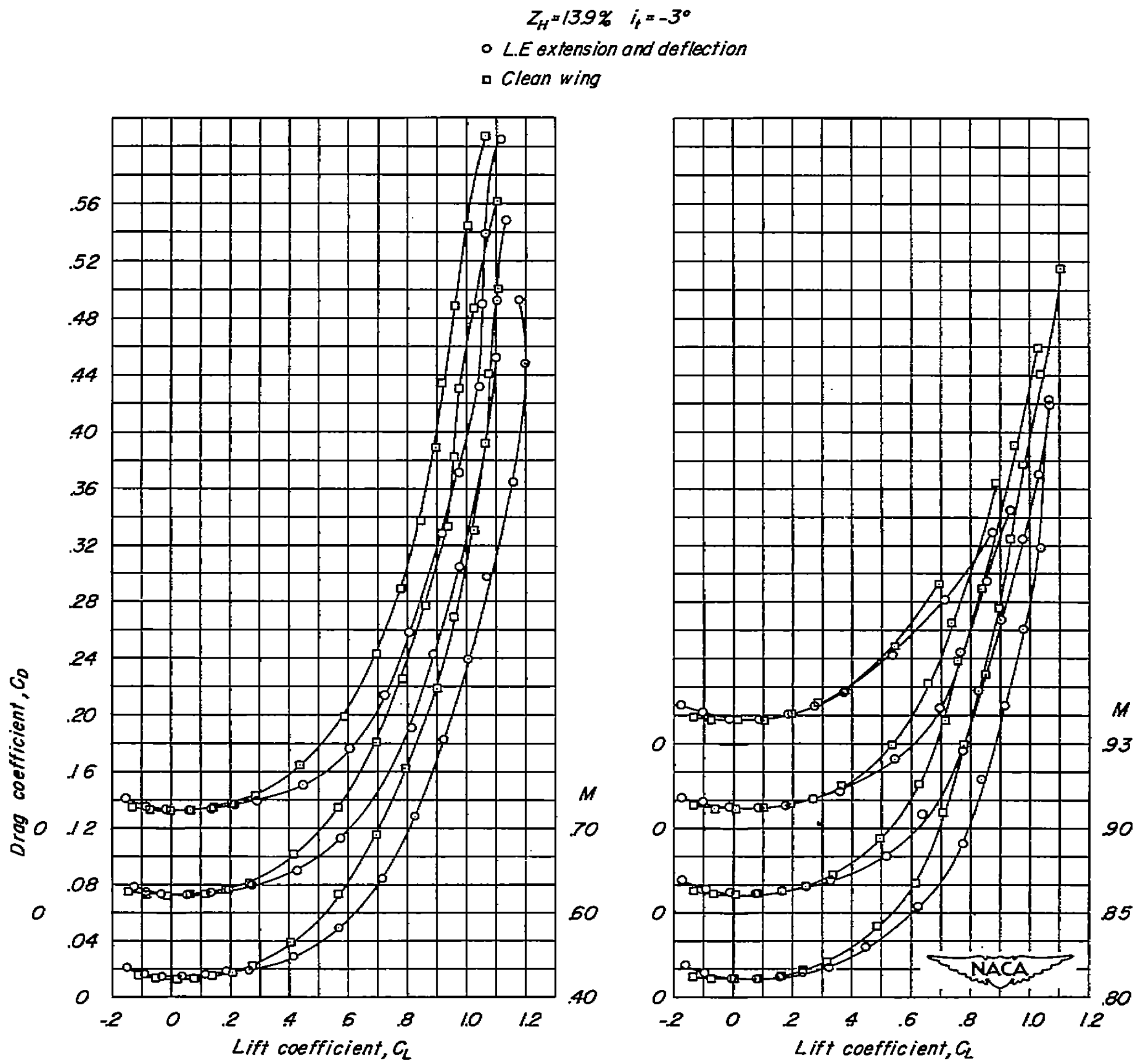
Figure 9.- Effects of a 6° full-span leading-edge-flap deflection and partial-span chord-extension on the aerodynamic characteristics in pitch of a general research model with tail configuration B. Z_H = 13.9 percent semispan; i_t = -3°.



(b) C_m against α.

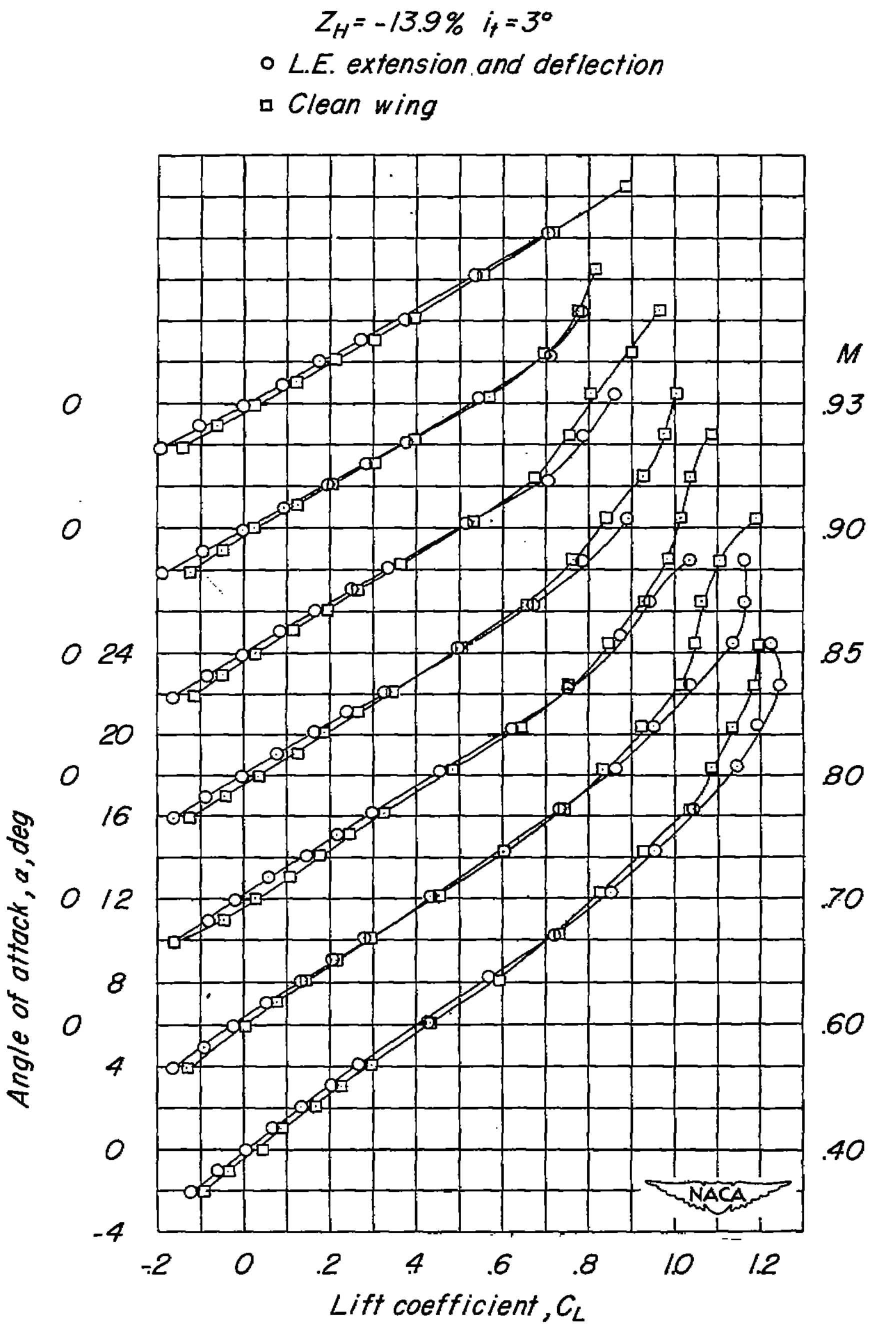
(c) C_m against C_L.

Figure 9.- Continued.



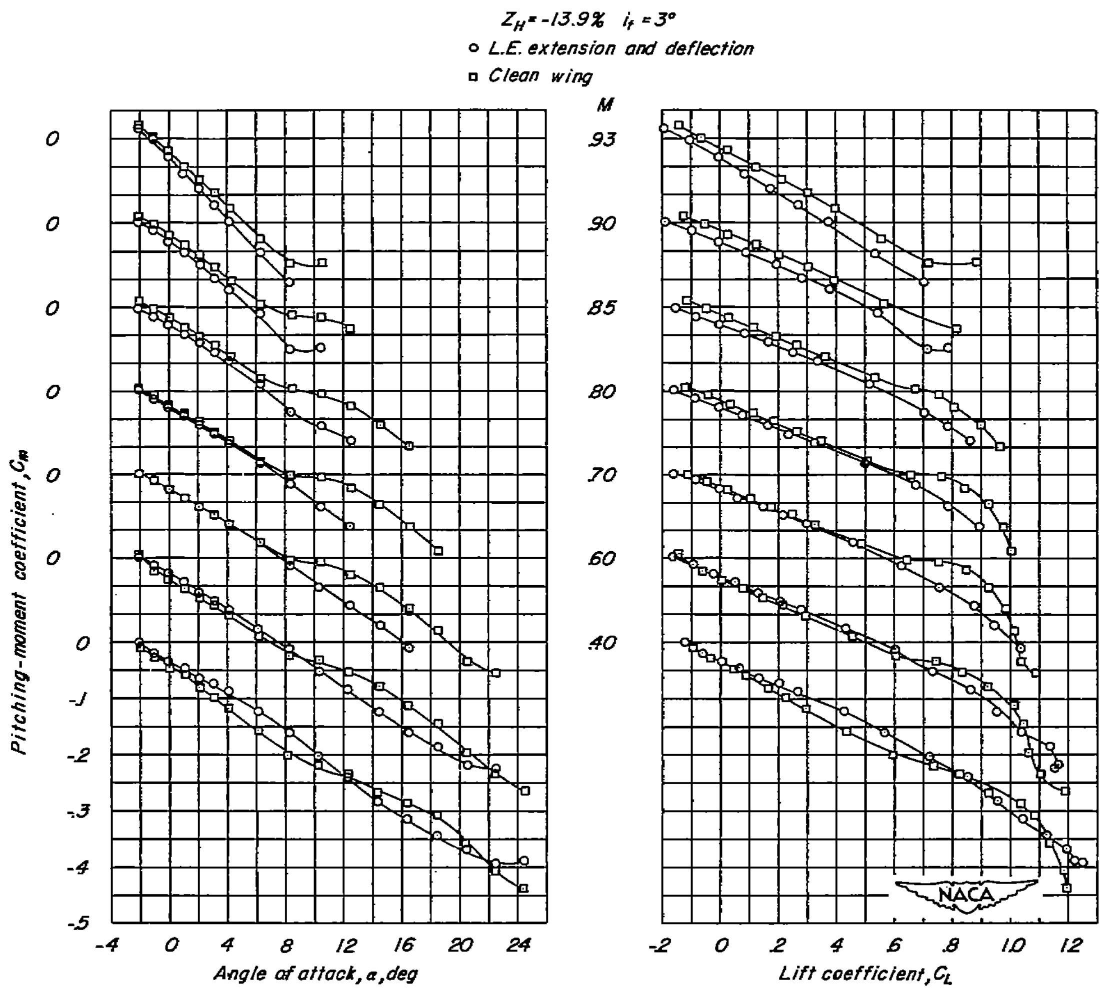
(d) C_D against C_L.

Figure 9.- Concluded.



(a) α against C_L.

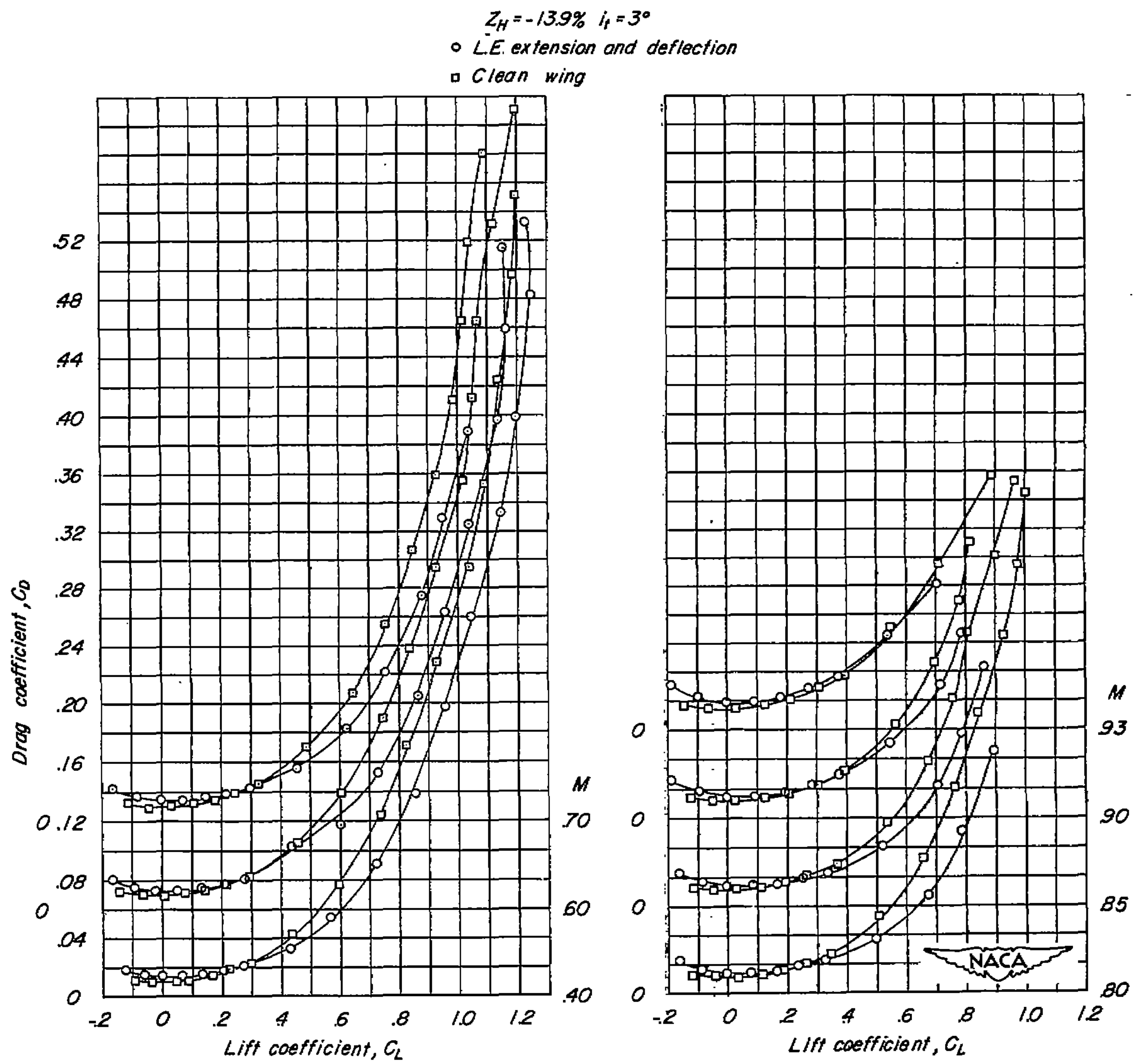
Figure 10.- Effects of a 6° full-span leading-edge-flap deflection and partial-span chord-extension on the aerodynamic characteristics in pitch of a general research model with tail configuration A. Z_H = -13.9 percent semispan; i_t = 3°.



(b) C_m against α.

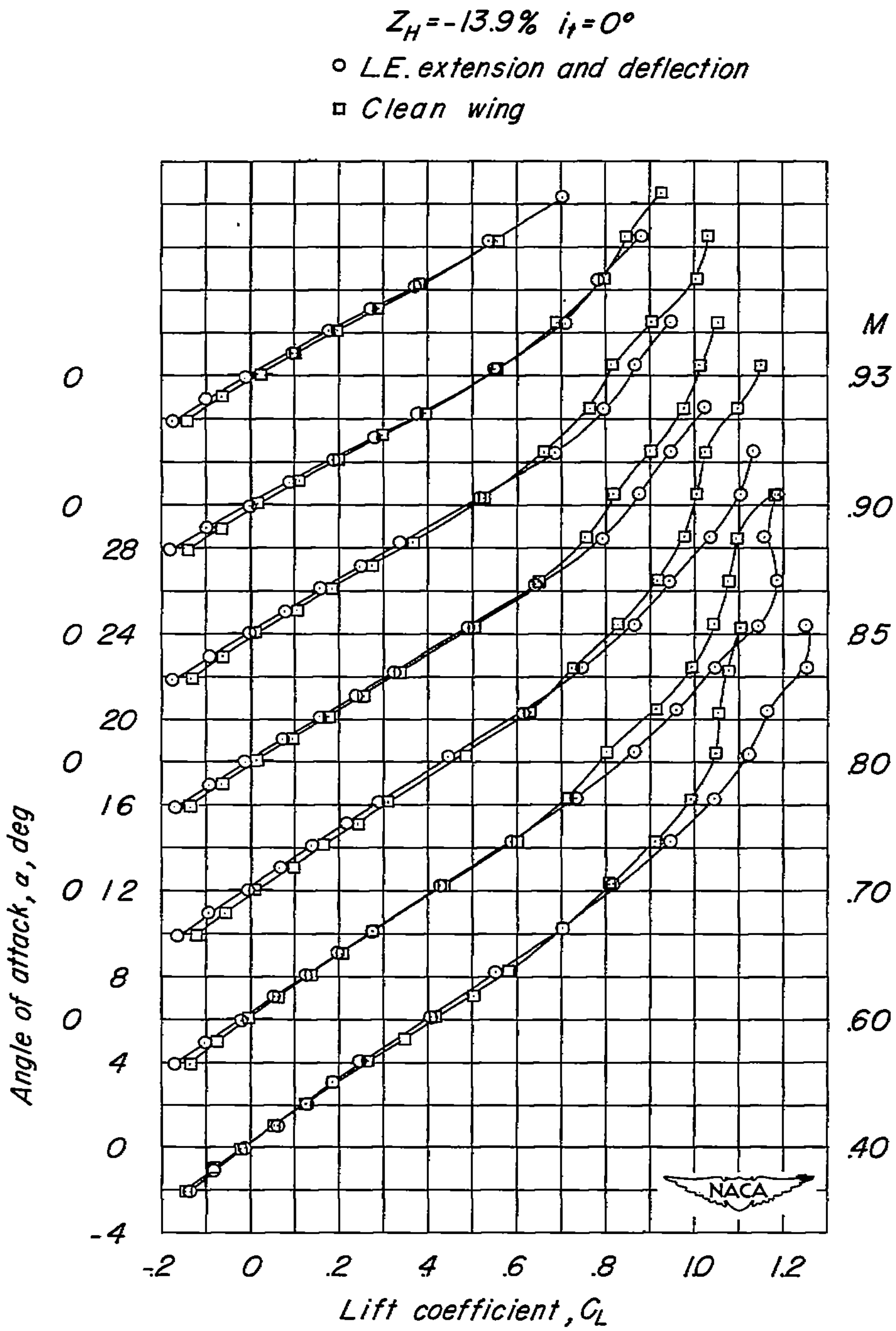
(c) C_m against C_L.

Figure 10.- Continued.



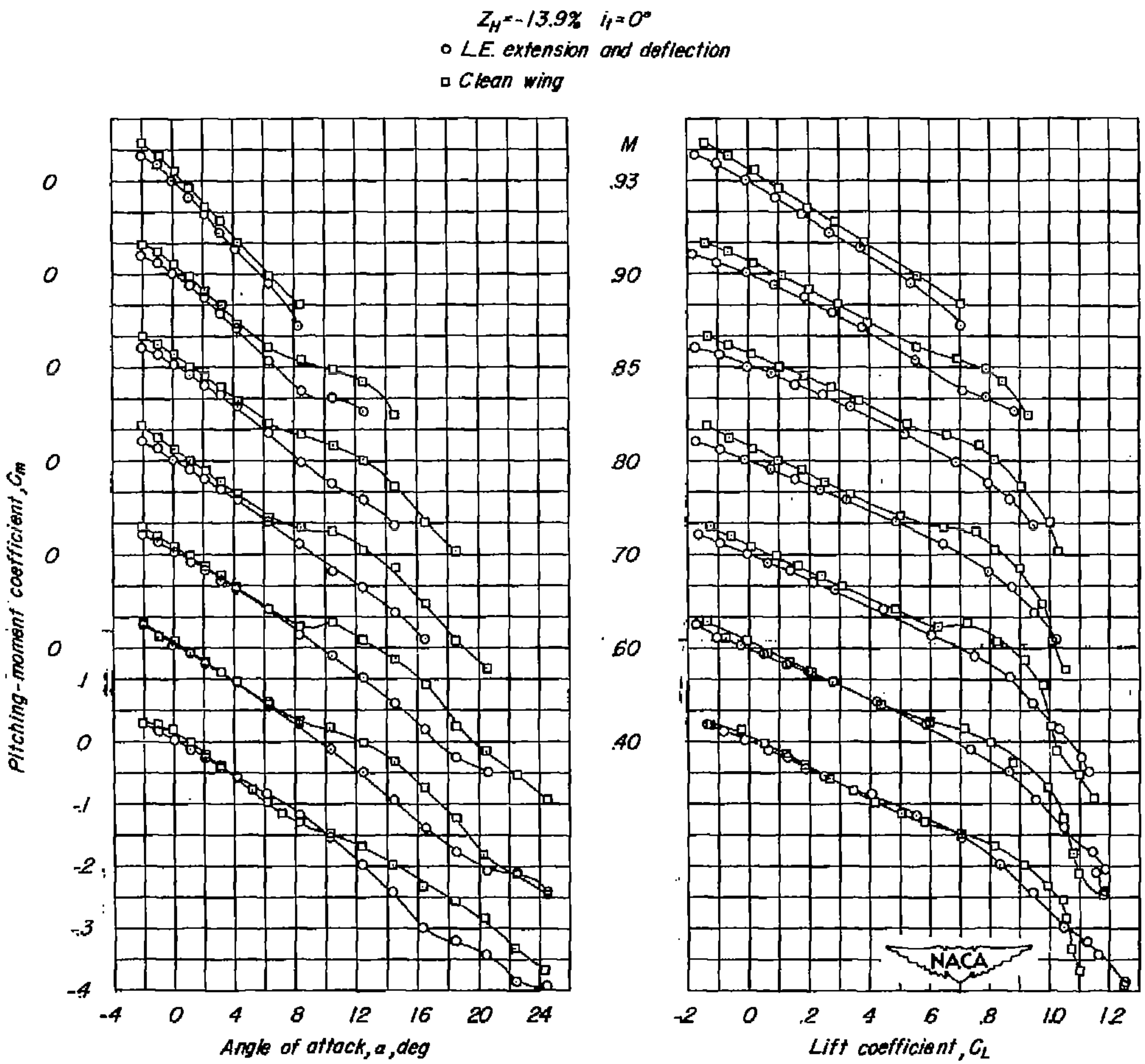
(d) C_D against C_L.

Figure 10.- Concluded.



(a) α against C_L.

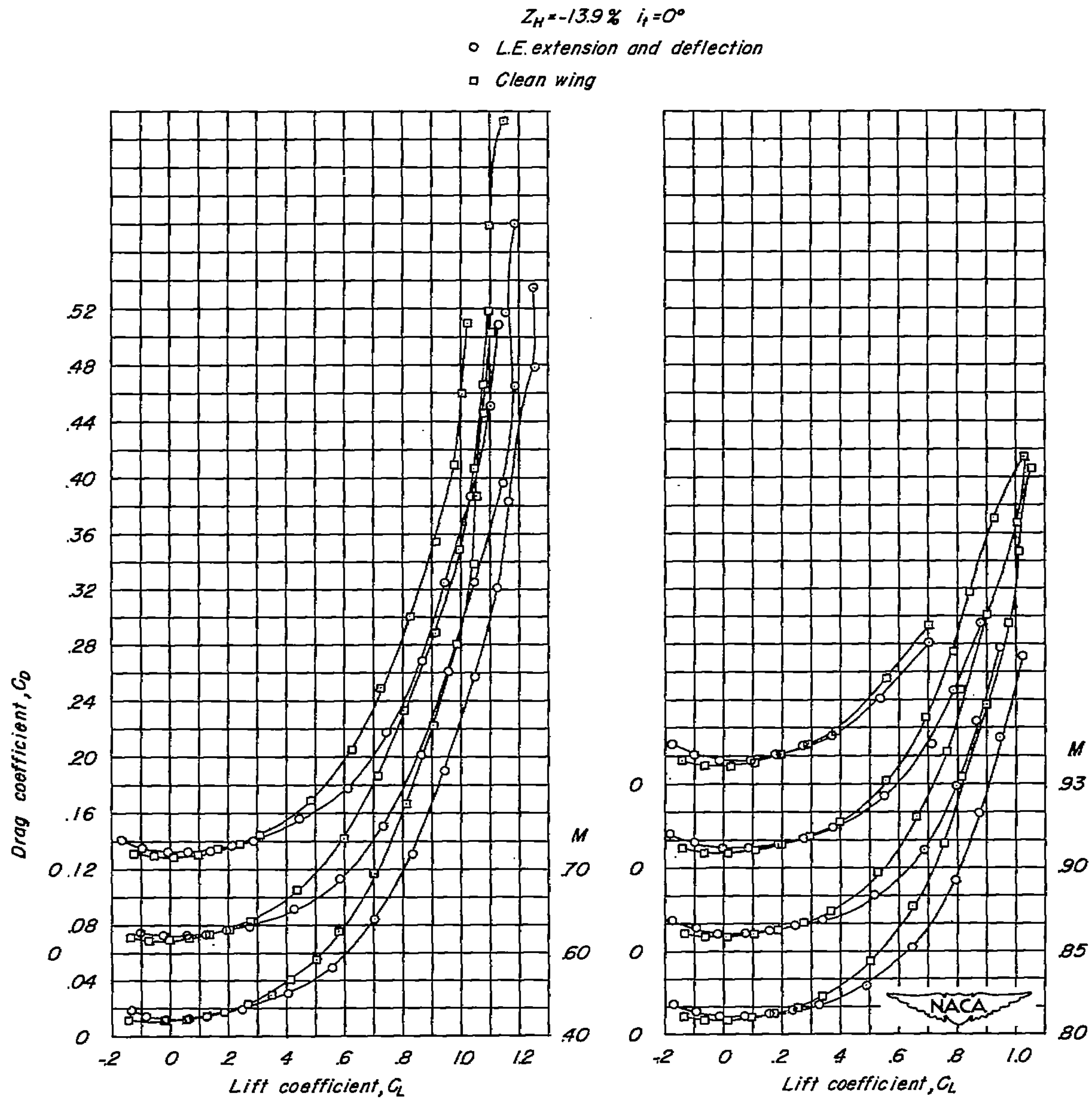
Figure 11.- Effects of a 6° full-span leading-edge-flap deflection and partial-span chord-extension on the aerodynamic characteristics in pitch of a general research model with tail configuration A. Z_H = -13.9 percent semispan; i_t = 0°.



(b) C_m against α.

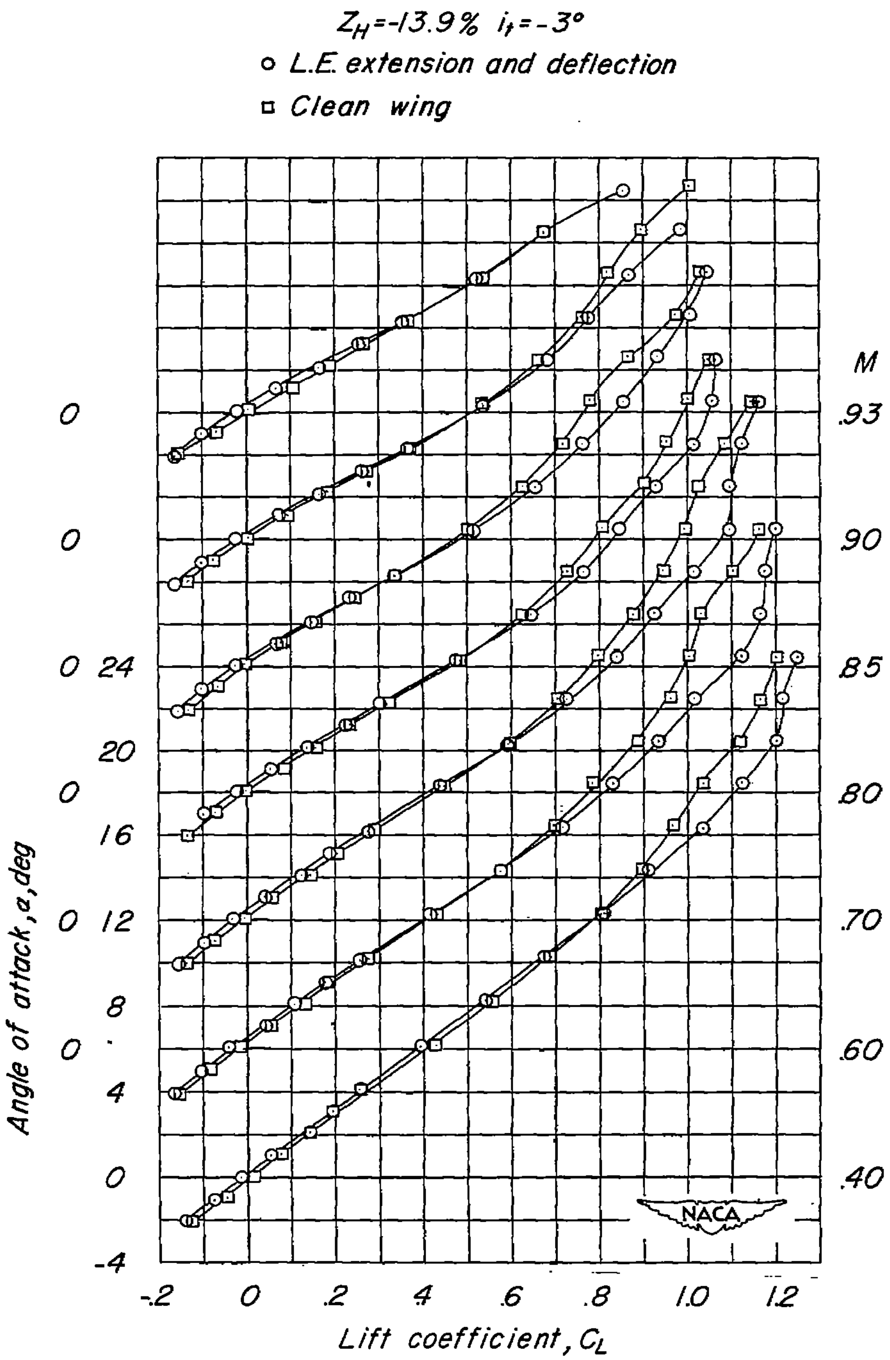
(c) C_m against C_L.

Figure 11.- Continued.



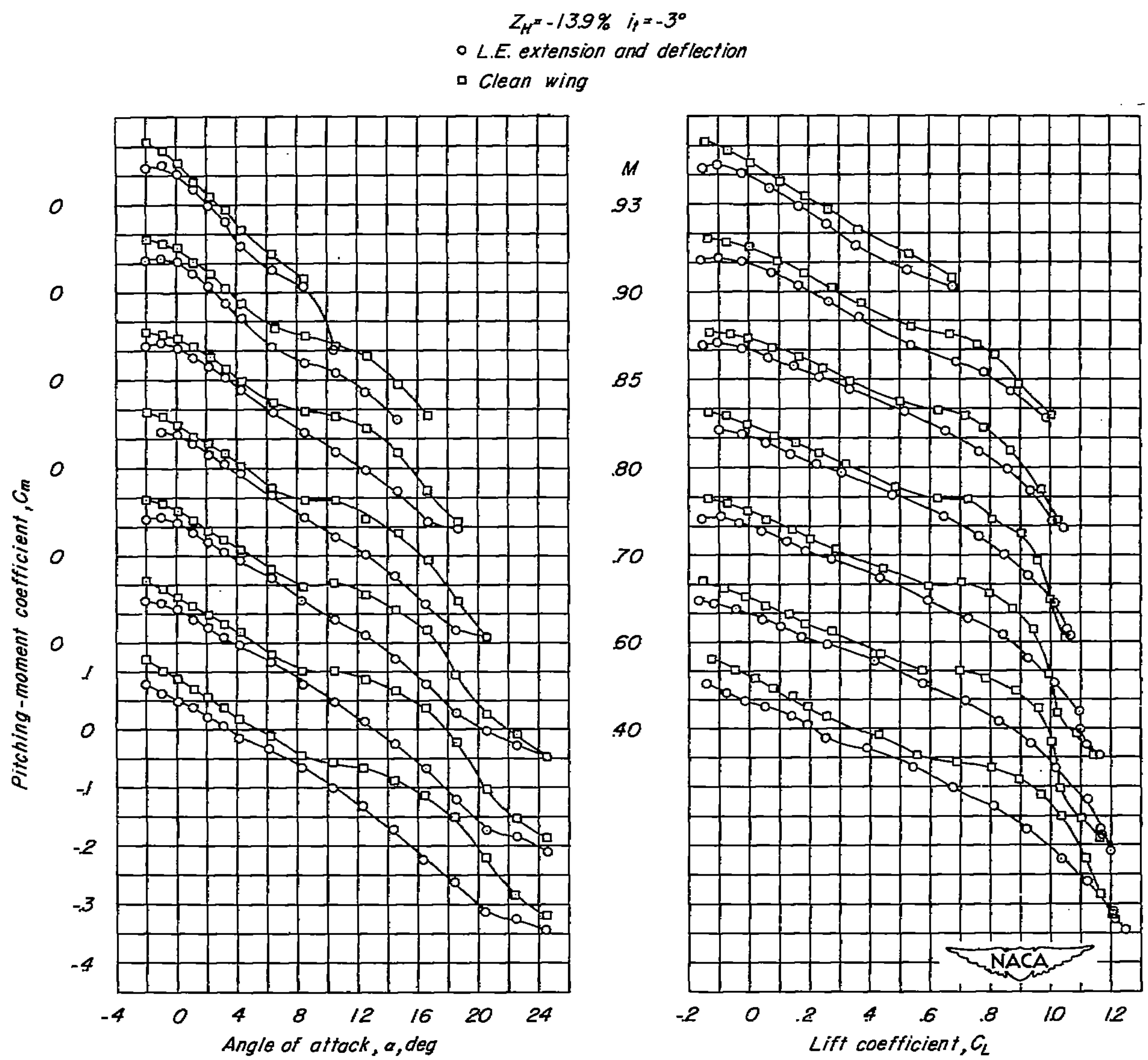
(d) C_D against C_L.

Figure 11.- Concluded.



(a) α against C_L.

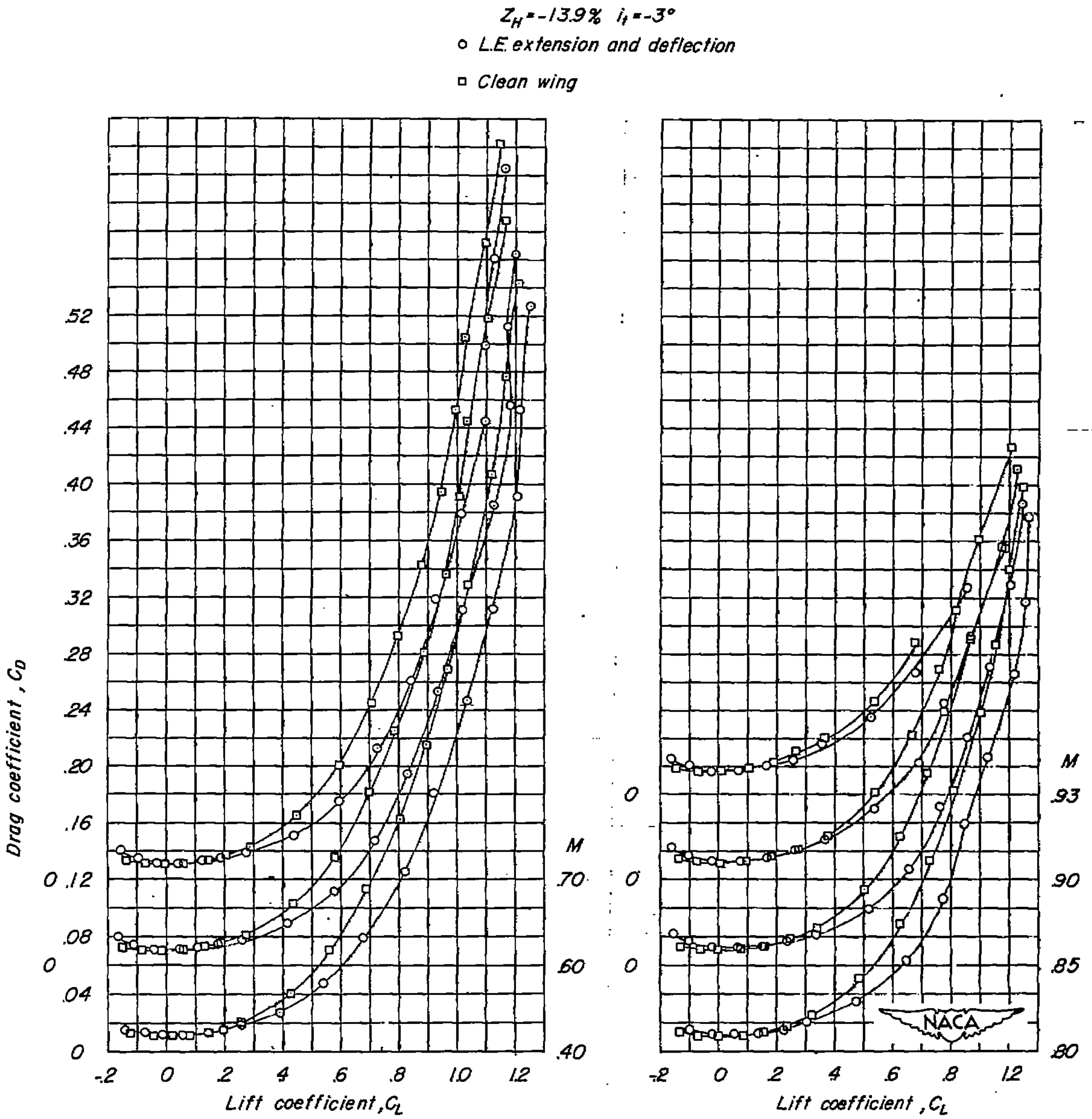
Figure 12.- Effects of a 6° full-span leading-edge-flap deflection and partial-span chord-extension on the aerodynamic characteristics in pitch of a general research model with tail configuration A. Z_H = -13.9 percent semispan; i_t = -3°.



(b) C_m against α.

(c) C_m against C_L.

Figure 12.- Continued.



(d) C_D against C_L.

Figure 12.- Concluded.

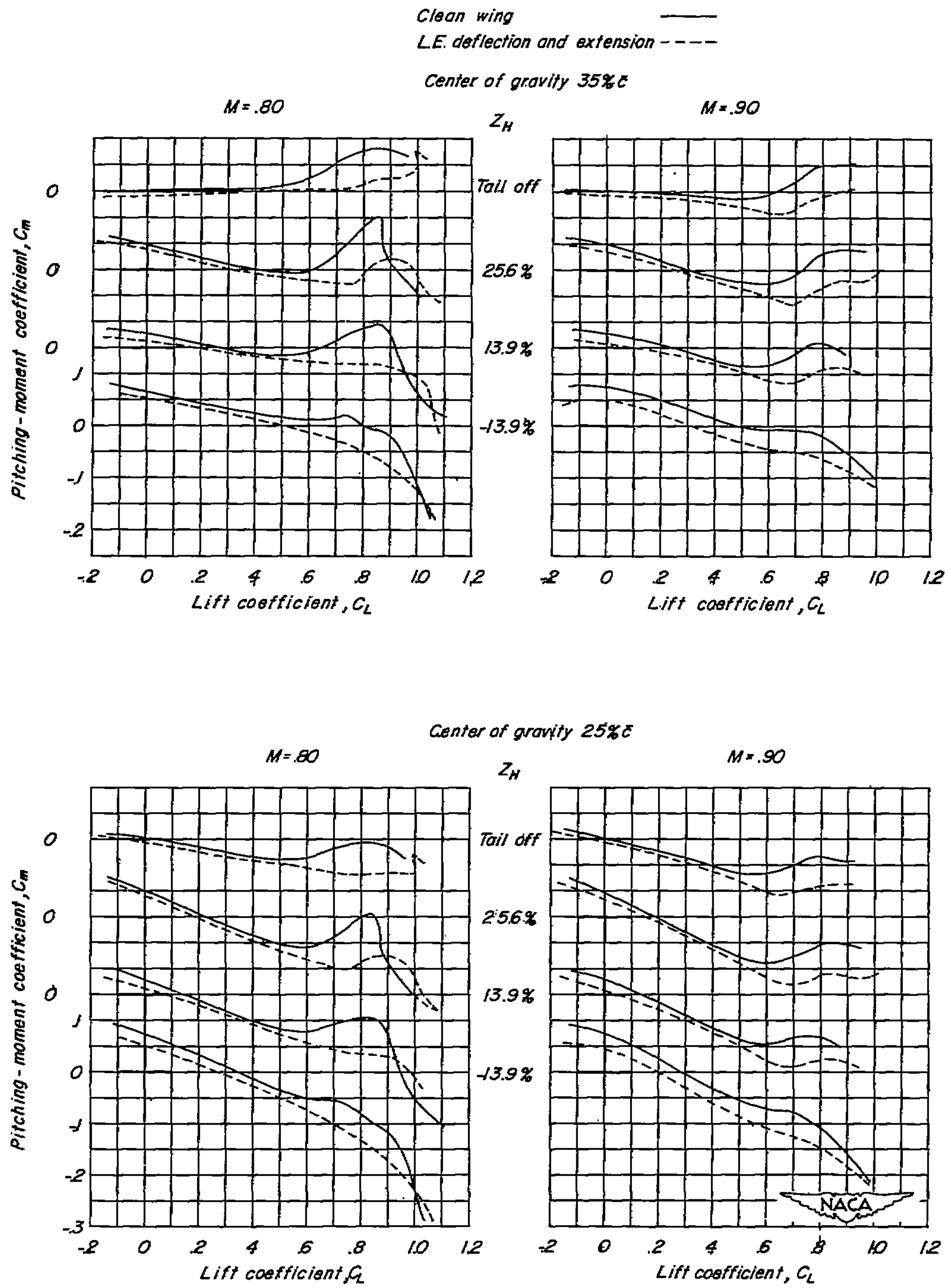


Figure 13.- Comparisons of pitching-moment characteristics at Mach numbers of 0.80 and 0.90 of a general research model with a 6° full-span leading-edge deflection and partial-span chord-extensions at three tail positions for two reference center-of-gravity locations. Tail-off data taken from reference 3; $i_t = -3°$.